COMPLIMENTS OF

THE CHAPMAN VALVE MANUFG. CO.

INDIAN ORCHARD, MASS.

Treas. Office, 72 Kilby Street, Boston, U. S. A.

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CATALOGUE

— OF —

GATE VALVES

AND

FIRE HYDRANTS,

MANUFACTURED BY THE

CHAPMAN VALVE MFG. CO

WITH AN ENGINEERING APPENDIX.

GENERAL OFFICE AND WORKS:

INDIAN ORCHARD, MASS.

TREASURER'S OFFICE:

72 KILBY STREET, BOSTON, MASS.

EDITION OF 1888.

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1888.

INDEX TO CATALOGUE.

We present this book to the consideration of the public with the hope that it may prove of value to them as a book of daily reference.

The various tables, formula. etc., have been collected from the works of reliable authors, with their consent, and are such as we think will be especially useful to engineers, machinists, and all having to do with the construction or maintenance of work of all kinds.

CHAPMAN VALVE MFG. CO.

INDIAN ORCHARD, MASS.

CHAPMAN VALVE MFG. CO.

BOSTON AND INDIAN ORCHARD, MASS.

JOSEPH W. SMITH, President.

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CHAPMAN VALVE MFG. CO.

In presenting the following detailed descriptions of the Chapman Gate Valves and the Chapman Fire Hydrants, we believe that the intrinsic value of the goods and the universal satisfaction they have given during the many years that they have been before the public, will warrant all we shall say of their especial adaptability to all uses for which they are intended

Kinds of Valves.

For ordinary practice there are made and in use two kinds of valves, commonly called "Globe" and "Gate" or "Open-way" valves. The former is so called from the special shape of the body of the valve: Its seat lies horizontally, in the center of the body, and every thing passing through the valve has to travel a course similar to a letter **S** turned horizontally thus **∽**. The result is that steam pipes are trapped with condensed water for half their diameter, thus largely destroying their carrying capacity, and so much resistance is offered to liquids that from 25 to 40 per cent. of the pressure is lost in forcing it through the valve. (*See pressure; loss of.*)

In order to have this valve as tight as may be, it is necessary to so put it into a line of pipe that the pressure will hold the disk against the seat, it is therefore but a single-faced valve and careless workmen are liable to put it in wrong.

The many makers of this style of valve have caused so much competition that the large majority are practically worthless, being rarely tight, and so, in every respect, fail to answer the requirements of a valve.

Gate Valves have none of the disadvantages of principle that the Globe Valves have—their seats are at right angles to the line of pipe and offer no obstruction whatever to the passage of either steam or water.

Some gate valves have but a single face and are practically worthless, for, if put into the pipe wrong, they are sure to leak, but all gates made by the Chapman Valve Manufacturing Company have double faces to their plug and double seats and are equally tight whichever face is put against the presssure.

Valves with Solid Gate.

The principle of using a solid gate, either wedge shaped or otherwise in the construction of open-way valves, is not new or novel; in fact, the first open-way valves ever made had solid gates, but they were not satisfactory. It was found to be practically impossible to make a solid gate valve that should be absolutely tight on either face when the seat was a hard metal, screwed or pinned into the body of the valve, and this trouble existed until John Chapman invented the principle of using a Solid Wedge-Shaped Gate in combination with a *dissimilar metal for a seat cast into the body of the valve.* This method of construction guaranteed the fitting, with absolute accuracy, of the seats to both faces of the wedge-shaped gate, and made possible the use of such a large variety of metals, in the gate and seats, that it is now possible to construct valves, of various combinations of metal, that will withstand nearly every known gas, vapor or liquid. The use of the proper dissimilar metals in the gate and seats prevents any and all tendency for the gates and seats to corrode together, and the valve will therefore always open easily. We employ this principle of construction in all our Gates, Valves and Hydrants.

Some manufacturers of open-way valves use plugs or gates made of loose disks with wedges, toggles, nuts, etc , to force them apart and against the seats. This is a great objection to their valves as the many pieces serve to complicate the valve, render it much more liable to get out of order, etc., in fact, the principle of all mechanics, "the simpler a piece of work the better," applies with truth to valves, and the Chapman Gate Valve is the only valve in existence having a Solid Wedge Gate *in combination with seats of a dissimilar metal.*

Details of Construction.

THE PLUG OR GATE.

The Plug or Gate in the Chapman Valve is a Solid Wedge made of different metals according to the use for which the valve is intended.

The angle between the two faces of the plug varies with the size and kind of valve but is always great enough to insure lifting the plug free from its seats with only a fraction of a turn of the spindle. To prevent the pressure on one side forcing it against

(*COPY.*)

MASS. INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

CHAPMAN VALVE MFG. CO., Indian Orchard, Mass.

Gentlemen :—We have tried the two samples of Alloys sent by you a few days ago, and find that marked "S" to melt at 454° F., or 234.5° centigrade.

"W" melts at 460° F., or 237.8° cent.

Yours truly,

JOHN M. ORDWAY,

Prof. Metallurgy and Industrial Chemistry.

The above letter is in response to a request of ours, that Prof. Ordway test the melting point of our Steam and Water Metal Alloys. Samples taken at random from our stock, being sent him, marked respectively "S" for steam, and "W" for water. It will be seen that he reports a much higher melting point than we had previously claimed.

(*See Elastic Force of Steam.*)

the seat on the other side, the edges of the plug are provided with grooves which run on guides in the sides of the body of the valve This holds the plug in place and it always rises and falls in the same plane without dragging on the seats or binding on the spindle.

SEATS.

The seats are of various alloys, each especially adapted to the use for which the valve is intended. We employ three different alloys in the seats of our regular stock of valves, while many more are used as circumstances require. These three alloys are called Steam Metal, Water Metal and Gas Metal — the name indicating the special use that each is intended for.

The Steam Metal alloy is made of Tin, Copper, and Antimony in suitable proportions to form a dense, tough metal which does not melt under a less heat than 430 deg. Fahrenheit. We guarantee valves having seats of this metal to stand a live steam pressure of 125 lbs. to the square inch, which pressure produces a heat much less than the melting point of our Steam Metal.

Superheated Steam will hold several hundred degrees of heat without showing any excessive pressure ; we do not, therefore, guarantee this metal to stand Superheated Steam.

Valves having Steam Metal seats can be used, not only for Steam and Water, but for any other vapor or liquid that will not affect the three metals forming it.

Water Metal Alloy is similar to the Steam Metal, has a higher melting point, but will not as well withstand the action of steam. We guarantee it for use on Water or other liquids, either hot or cold, that do not contain a very large per cent. of acid.

Gas Metal Alloy is made of Lead, Tin, Copper and Antimony in suitable proportions, and has a melting point of 450 deg. Fahrenheit.

It will withstand the action of all kinds of illuminating Gas, Ammonia, or Ammoniacal Vapors, weak dilutions of commercial acids and similar vapors and liquids, either hot or cold.

METALS.

All of our Composition is made from Ingot Metals and contains ninety (90) per cent of copper. The result is a Bronze or Gun Metal.

Our Iron Castings are made from the best No. 1 Anthracite Pig and Machinery Scrap.

PATTERNS AND CORE BOXES.

Our Patterns embrace over 1500 different forms and sizes of Valves and Hydrants and we are constantly adding to them All the smallest and most of the medium sized Patterns and Core Boxes are of Metal, and all others are Metal-Bound, and thus we insure smooth, uniform castings that conform exactly to the sizes and shapes desired.

MACHINERY AND TOOLS.

All of our Machinery and Tools are special in their nature, nearly every one being made from our own designs and each having its own specific work to do. Every hole that is drilled, every thread that is cut, or flange that is finished, is brought exactly to its size and must exactly agree with its steel gauge or template. We can thus guarantee perfection of workmanship, and, to a large extent, interchangeability of parts.

TESTING.

Each Valve and Hydrant, when completed, is subjected to a steam or hydraulic pressure varying from 200 lbs to 2,000 lbs. or more, to the square inch, and if any valve fails to stand its test it is not allowed to leave the works.

BUILDINGS.

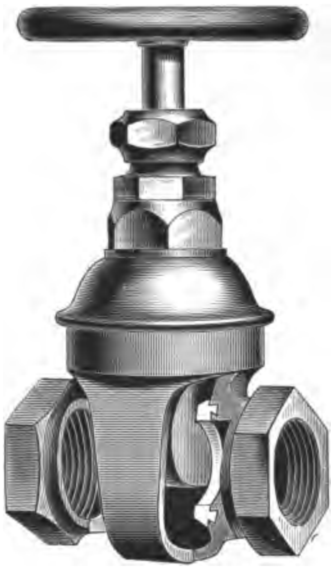
Our shops are large, well and conveniently arranged for our own individual use. We have had in process of construction some new building or addition to our existing ones nearly all the time for the past few years, and large additions, doubling our present capacity, are now in process of construction necessitated by the popular demand for our goods.

We claim

PERFECTION OF PRINCIPLE,
PERFECTION OF CASTINGS,
PERFECTION OF MACHINERY AND TOOLS,
PERFECTION OF SYSTEM,
PERFECTION OF WORKMANSHIP,
PERFECTION OF FINISH.

We invite your attention to the following pages for details of our principal kinds of Valves and Hydrants.

CHAPMAN VALVE MFG. CO.



COMPOSITION VALVE.

STATIONARY SPINDLE. SCREW ENDS.

COMPOSITION VALVES.

STATIONARY SPINDLES.

Regular Sizes, from ½ inch to 4 inches, inclusive.

SCREW OR FLANGE ENDS.

These valves are for use on Steam, Water, or any other vapor or liquid that will not affect our Composition and Steam Metal.

The Body, Cap, Plug, Spindle, etc., are of Composition, and the Seats of Steam Metal.

These valves are compact in form, neat in finish, and are suitable for use on engines and pumps, or any finished work, as well as for the innumerable other places where a valve is needed.

Larger sizes than 4 inches are made from patterns with flange tops.

We keep large numbers of the standard sizes of these valves in stock with which to fill quick orders.

COMPOSITION STEAM AND WATER VALVES.

STATIONARY SPINDLES. STEAM METAL SEATS.

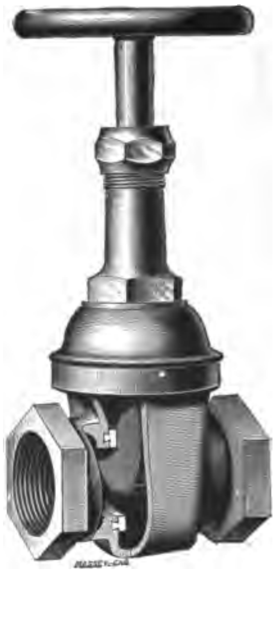
PRINCIPAL DIMENSIONS.

Diameter of Opening, in.,	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4
Face to Face, Screw Ends,	2 3/8	2 3/4	3 3/8	3 11/16	4 1/8	4 3/4	5 9/16	6 5/8	8 3/8	8 15/16
Face to Face, Flange Ends,	2 9/16	3	3 9/16	3 15/16	4 5/16	5 1/4	5 3/4	7	8 1/4	8 7/8
Diameter of Flanges,	3	3	4	4 1/2	5	6	7	7	8 1/2	9
Height of Valve, Center of Pipe to Top of Wheel,	4 1/8	4 3/4	5 1/4	5 3/4	6 5/8	7 5/8	9	10 3/8	12 1/4	13 1/8
Diameter of Wheel,	2 5/8	3 1/8	3 3/8	3 11/16	4	4 7/16	5	5 7/8	7 1/8	8 1/2

UNLESS OTHERWISE ORDERED,

These Valves will be furnished with Stationary Spindles and Hand Wheels, and open by Turning to the Left.

CHAPMAN VALVE MFG. CO.



COMPOSITION VALVE.

RISING SPINDLE. SCREW ENDS.

COMPOSITION VALVES.

RISING SPINDLE.

Regular Sizes, ½ inch to 4 inches, inclusive.

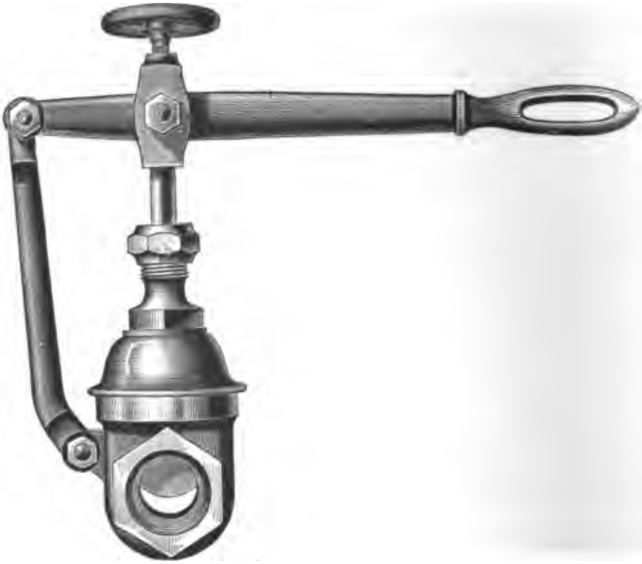
EITHER SCREW OR FLANGE ENDS.

We make a full line of Composition Valves having a rising spindle and hand wheel.

These Valves occupy a trifle more room than those with Stationary Spindles, but they have the advantage of always showing whether the valve is shut, or partly or fully open.

For use as a feed valve on pumps or any apparatus requiring delicate adjustment it is a very valuable valve.

Its dimensions, except from center of pipe to top of hand wheel, are the same as in Stationary Spindle Valves. It is made of the same materials and will stand the same tests and use.



COMPOSITION VALVE.

SLIDING SPINDLE AND LEVER. SCREW ENDS.

COMPOSITION VALVES.

SLIDING SPINDLE AND LEVER.

Regular Sizes, $\frac{1}{2}$ inch to 4 inches, inclusive.

EITHER SCREW OR FLANGE ENDS.

These valves are for use under moderate pressure where a quick motion is desirable, and the water-hammer caused by it will do no damage. They open or close with one movement of the lever, and can be held in any position by the binder-wheel.

They are especially adapted for use as throttles on steam engines, hammers or elevators, on hose valves, stand-pipes, tanks, etc.

When used in connection with a spring to close them, they make a perfect whistle valve. We know of several that have been in daily use for years and that are still good for many years more.

The dimensions from face to face of screw or flange ends, and the diameter of flanges, are the same as for stationary spindle valves.

CHAPMAN VALVE MFG. CO.

COMPOSITION BIBB VALVE.

COMPOSITION BIBB VALVES.

Regular Sizes, ½ inch to 2 inches, inclusive.

EITHER PLAIN OR THREADED FOR HOSE.

These valves have been designed to meet a call for something better than the ordinary Bibb Cock. They can be used with either hot or cold water and will be found especially valuable for use with kerosene or other oils. We can furnish them with a quick thread on the spindle and in plain brass or nickel plated as desired. Architects, Engineers and the Trade have strongly commended these bibbs, and they are certain to supersede the ordinary compression bibb in first-class work.

CHAPMAN VALVE MFG. CO.

COMPOSITION HOSE VALVE.

COMPOSITION HOSE VALVES.

Regular Sizes, $\frac{3}{4}$ inch to 3 inches, inclusive.

WITH OR WITHOUT CAP FOR HOSE END.

Unless otherwise ordered we shall cut thread on Hose End (our standard) full V, as follows:

Diameter of Opening, in.,	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3
Outside Diam., Th'd on Hose End,	$1\frac{1}{16}$	$1\frac{13}{32}$	$1\frac{11}{16}$	$1\frac{31}{32}$	$2\frac{45}{64}$	$3\frac{1}{16}$	$3\frac{26}{64}$
Diam. Bottom, Th'd on Hose End,	$\frac{61}{64}$	$1\frac{18}{64}$	$1\frac{35}{64}$	$1\frac{53}{64}$	$2\frac{1}{2}$	$2\frac{55}{64}$	$3\frac{5}{8}$
No. Threads per inch Hose End,	11	11	11	11	$7\frac{1}{2}$	7	7

CHAPMAN VALVE MFG. CO.

AUTOMATIC DRIP VALVES.

VALVES WITH AUTOMATIC DRIP.

ALL SIZES OF VALVES,

From one inch upward, can be supplied with the Automatic Drip or Waste, and are especially adapted for

RAILROAD WATER PIPES,

FIRE STAND PIPES,

STREET SPRINKLING STAND PIPES,

HAND HOSE HYDRANTS,

AND SIDE-WALK VALVES, ETC., ETC.

In many cases it is necessary to drain the water from a pipe, after the supply has been cut off, by closing the main valve. To accomplish this it has heretofore been necessary to put a T into the pipe with a valve on it, that had to be opened after the main valve was closed. This method is expensive, troublesome, and not sure, as the existence of the drain valve is sometimes forgotten; especially if underground. To obviate these troubles, we have recently incorporated into our valve an Automatic Drip, for purposes where drip is desirable in a valve. This drip is the same as applied to our Hydrants; it has met with an unusual degree of approval by all parties who have used them. We have lately put in special machinery for the manufacture of these, so that we can furnish in large quantities and at fair cost. We know all parties using these valves will render the verdict of "A perfect Automatic Drip."

CHAPMAN VALVE MFG. CO.

SERVICE VALVES FOR WATER WORKS.

SERVICE VALVES FOR WATER WORKS.

Sizes, ½ inch to 2 inches, inclusive.

We desire to call especial attention of water works, and the public, to our Service Valves. It is a well-known fact that the usual plug cock works hard, and often becomes wedged, and refuses to do its duty at all. Our Water Service Valve is intended to fill a long-felt want in this direction. It is made with a heavy iron body, and heavy composition mountings, especially adapted for water services, and are made reliable to resist the general hard usage to which a valve of this kind is liable. We have thousands of these Valves in use, and they are giving universal satisfaction. Any water works superintendent wishing a sample for examination and test, will be furnished with such upon application.

GAS, OIL AND AMMONIA VALVES.

FOR ORDINARY PRESSURE.

These valves are made from ordinary heavy patterns provided with iron plugs, wrought iron or steel spindles, large stuffing boxes with joints between body and cap, and cap and stuffing box carefully faced. These valves are made with particular reference to holding the gases of ammonia and other volatile or penetrative substances under ordinary or light pressures; are used largely in the manufacture of ice and for refrigerating purposes.

CHAPMAN VALVE MFG. CO.

AMMONIA VALVES.

For Medium Pressure.

ALL IRON, WITH SPECIAL BABBITT SEATS AND PACKING RINGS.

AMMONIA VALVES.

For Medium Pressure.

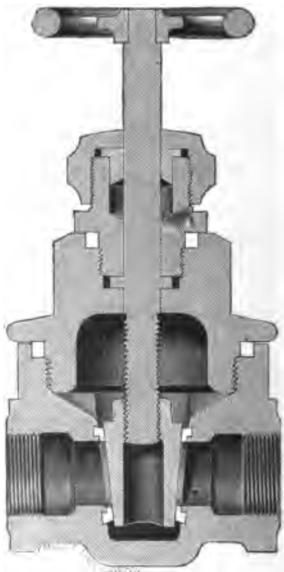
ALL IRON, WITH SPECIAL BABBITT SEATS AND PACKING RINGS.

To withstand 1,000 Pounds Working Pressure.

To meet the large demand for a Medium Pressure Ammonia Valve, we have completed a set of patterns for valves that will withstand a working pressure of 1,000 pounds per square inch.

They are for use on Gas, Oil, Ammonia, or any other similar material or vapor. They do not corrode, and long experience has proved that the "Chapman" is the only practical Gas and Ammonia Valve in use.

CHAPMAN VALVE MFG. CO.



AMMONIA VALVES.

For Heavy Pressure.

AMMONIA VALVES.

For Heavy Pressure.

Sizes, ½ inch to 4 inches, inclusive.

These Valves are made from extraordinary heavy patterns provided with iron plugs, wrought iron or steel spindles, extra large stuffing boxes, special seats, and packing rings to make joints of cap and stuffing box. These Valves are made with particular reference to holding the gases of ammonia and other volatile and penetrative substances; are used largely in the manufacture of ice and refrigerating purposes.

CHAPMAN VALVE MFG. CO.

IRON BODY VALVE.

COMPOSITION MOUNTINGS. STATIONARY SPINDLE AND HAND-WHEEL. SCREW TOP. SCREW ENDS.

IRON BODY VALVES.

COMPOSITION MOUNTINGS. STATIONARY SPINDLES AND HAND-WHEELS. SCREW TOP. SCREW OR FLANGE ENDS.

Regular Size, ½ inch to 4 inches, inclusive.

These valves are made with Cast Iron Bodies, Caps and Wheels, and Composition Plugs or Gates, Spindles, and Stuffing Boxes; the seats are of Steam Metal. They are for use on steam and water, or any other vapors or liquids that these alloys will stand.

They are preferable to Composition valves, especially from 2 inches to 4 inches in diameter, where strength is desired, as the Cast Iron body is much stiffer than the Composition, and will stand more hard use.

They are very neat and compact in form, and make a very superior valve for all uses.

We also make these same sizes and styles with Sliding Spindles and Levers, similar in design to Composition Valves.

These valves are kept regularly in stock, and ordinary orders can be filled at short notice.

CHAPMAN VALVE MFG. CO.

IRON BODY VALVE.

COMPOSITION MOUNTINGS. STATIONARY SPINDLE AND HAND-WHEEL, SCREW TOP. FLANGE ENDS.

IRON BODY STEAM AND WATER VALVES.

COMPOSITION MOUNTINGS. SCREW TOP. STEAM METAL SEATS.

PRINCIPAL DIMENSIONS.

Diameter of Opening, in.,	½	¾	1	1¼	1½	2	2½	3	3½	4
Face to Face, Screw Ends,	2¾	3⅜	3⅞	4¼	4¾	5¾	6⅝	7½	8⅜	9⅝
Face to Face, Flange Ends,	3¼	3⅝	4¼	4¾	5¼	5⅝	6⅜	7⅛	8¼	9⅜
Diameter of Flanges,	3	3	4	4½	5	6	7	7	8½	9
Height of Valve, Center of Pipe to Top of Wheel,	4½	5⅛	6	6⅝	7⅜	8¼	10	11	12¼	13¼
Diameter of Hand Wheel,	2⅝	3⅛	3⅜	3¾	4	5	5⅞	6⅞	7⅞	8½

UNLESS OTHERWISE ORDERED,

These Valves will be furnished with Stationary Spindles and Hand Wheels, and open by Turning to the Left.

CHAPMAN VALVE MFG. CO.

IRON BODY VALVE.

COMPOSITION MOUNTINGS. STATIONARY SPINDLE AND HAND WHEEL. FLANGE TOP. SCREW ENDS.

IRON BODY VALVES.

COMPOSITION MOUNTINGS. STATIONARY SPINDLES AND HAND WHEELS. FLANGE TOP. SCREW OR FLANGE ENDS.

Regular Sizes, $2\frac{1}{2}$ inches to 24 inches, inclusive.

These valves are made with Cast Iron Bodies, Caps and Wheels, and Composition Spindles, Stuffing Boxes and Plugs, up to, and including, 4 inches in diameter; above that the Plugs are of Cast Iron with Composition Faces and Bushings for Spindle. The Seats are of Steam Metal Alloy. They are for use on Steam and Water, or any other vapors or liquids that these metals will stand.

Being made with a heavy bolted flange between the body and cap, they make a very strong and serviceable valve, which can be quickly and easily taken apart to clean out any sediment that may collect. These flanges fit together with a Metal Joint, *no Gasket or Packing being used.*

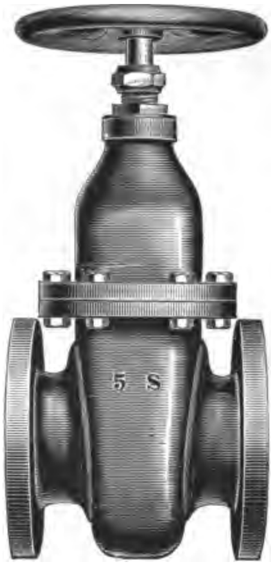
The larger sizes can be fitted with either bevel or upright gearing as desired. The bevel gearing for these valves is applied in the same manner as to our Water Gates. (See Page 54)

All of these valves above 14 inches in diameter have our improved Bolt Gland Stuffing Boxes, the same as are used on our Water Gates. (See Page 50.)

We make this style of valve with Sliding Spindle and Lever, similar in arrangement to the Composition Lever Valves. (See Page 14.)

All sizes of these valves are kept in stock, and ordinary orders can be filled at short notice.

CHAPMAN VALVE MFG. CO.



IRON BODY VALVE.

COMPOSITION MOUNTINGS. STATIONARY SPINDLE AND HAND WHEEL. FLANGE TOP. FLANGE ENDS.

IRON BODY STEAM AND WATER VALVES.

COMPOSITION MOUNTINGS. FLANGE TOP. STEAM METAL SEATS.

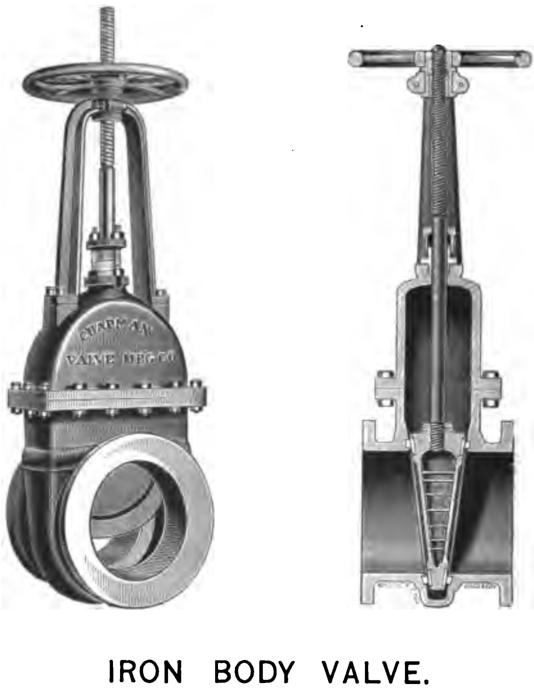
PRINCIPAL DIMENSIONS.

Diameter of Opening, inches,	2½	3	3½	4	4½	5	6	7	8	10	12	14	15	16	18	20	24
Face to Face, Screw Ends,	6⅝	7½	8⅜	9⅝	9¾	10¼	11⅜	12⅛	12½								
Face to Face, Flange Ends,	7⅞	8¼	8⅞	9⅜	10¼	9⅝	10⅞	11½	11⅞	13⅝	14⅝	15⅞	16⅝	18¾	20	21	24
Diameter of Flanges,	7	7	8½	9	9½	10	11	12	13	16	18	21	22	23	25	27	31
Hgt. of Valve, Cen. of Pipe to top of Wheel,	10¼	11	12¼	13¼	15$\frac{1}{16}$	17⅛	20	22⅜	24	29	33	35½	39	39¾	45	47	54½
Diameter of Wheel,	5⅞	6⅞	7¾	8½	10	10	12	12¾	14	15	16	17	18	18	20	22	24

UNLESS OTHERWISE ORDERED,

These Valves will be Furnished with Stationary Spindles and Hand Wheels, and open by Turning to the Left.

CHAPMAN VALVE MFG. CO.



IRON BODY VALVE.

OUTSIDE SCREW AND YOKE. STATIONARY HAND WHEEL.

FLANGE ENDS.

IRON BODY VALVES.

WITH OUTSIDE SCREW AND YOKE.

Regular Sizes $2\frac{1}{2}$ inches to 24 inches, inclusive.

On the medium and larger sizes of steam or water valves that are opened and closed often, in use as Throttles, etc , it has been found desirable to have the screw on the outside of the valve, where it can be readily cleaned and oiled.

To meet the demand for this class of Valves, we have completed a line of patterns having Outside Screws and Yokes with Stationary Hand Wheels.

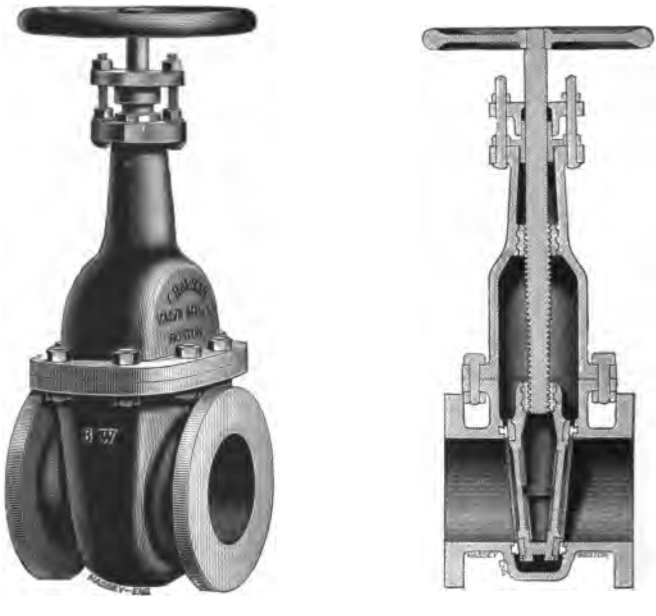
In other makes of valves having outside screws, the Hand Wheel is usually fastened to the spindle, a form of construction that has many obvious disadvantages, especially if it is desired to use the valve lying on one side.

This form of construction can be applied to any of our regular kinds and sizes of valves.

It is made with the same care as all of our work, is interchangeable in all its parts, and for certain uses, is recommended as the best open-way valve made.

Unless otherwise ordered, face to face and diameter end flanges same dimensions as stationary spindle valves. (Page 37.)

CHAPMAN VALVE MFG. CO.



IRON BODY VALVE.

QUICK OPENING, COMPOUND SCREW. FLANGE ENDS.

IRON BODY VALVES.

QUICK OPENING. COMPOUND SCREW.

Regular Sizes, $2\frac{1}{2}$ inches, upward.

On account of the amount of space necessary to work the larger sizes of Quick Opening Lever Valves, and the strain brought upon the pipes by the almost instantaneous stopping of the current by their use, we have designed and introduced a Quick Opening Valve having a Compound Screw and Hand Wheel, or Nut.

Its construction is such that the plug, or gate, rises on the spindle and at the same time the spindle rises out of the valve, thus giving a double or compound motion. The pitch of the threads is such that these valves open easily and quickly, a six (6) inch valve opening in about five (5) turns and other sizes in similar proportions; this is a quick enough motion for all ordinary purposes, and yet this form of valve is capable of a slow uniform motion unattainable with a lever valve.

These valves although but recently introduced have gained a high reputation in use as Throttles on Engines, Feed Valves for large pumps, Supply and Drain Valves for Stand Pipes, Tanks, etc.

This motion can be applied to any of our valves above 2 inches diameter.

Unless otherwise ordered, face to face and diameter end flanges same as stationary spindle. (Page 37.)

CHAPMAN VALVE MFG. CO.

IRON VALVE.

EXTRA HEAVY PRESSURE.

2000 Lbs. per Sq. Inch.

HEAVY PRESSURE VALVES.

FOR USE ON

PUMPS, HYDRAULIC MINING MACHINERY, OIL PUMPING LINES, ETC.

We wish to call espcial attention to the trade and public to the fact that the Chapman, under heavy pressure, will work easier than any other valve in the market, for these reasons: The plug is in one piece and guided upon its edge by splines in the body, which engage with it, enabling the plug to rise and fall without coming in contact with the seats. This is the case with all "Loose Disc" valves, especially at point of opening or closing, when the outlet loose Disc is crowded over to the seat, and becomes a source of friction until nearly open, or vice versa. Besides this, our valves are so constructed as to hold the collar of spindle between two immovable faces of metal, which admits the stuffing boxes, which are of large capacity, to be independent of any thrusts, so that the packing may always be elastic around the spindle. The faces of plug and seat being dissimilar, will not oxidize and stick when closed, and the superior workmanship added to these, make the "Chapman" always the favorite under heavy pressures. We have a large number of these special valves working under very heavy pressure, and testimonials will be furnished upon application. We can furnish nearly anything in the heavy pressure line of valves.

STATIONARY SPINDLE.

OUTSIDE SCREW AND YOKE.

Gas Valves with Outside Screw and Yoke.

Special prices upon application.

IRON, GAS, OIL AND AMMONIA VALVES.

Sizes, 2½ to 48 inches, inclusive.

These Valves are made with all iron parts (except seats), with bolted top, wrought iron spindles, tinned above collar to prevent rust; they are made with either stationary spindle or outside screw and yoke. Either screw or flange ends, with the bolt gland stuffing box on all sizes above four inches.

Special attention is called to the peculiar fitness of the Babbitt Metal Seats in all gas valves, and also to the outside screw and yoke valve for inside gas work, where an indicator is desirable.

IRON, GAS, OIL AND AMMONIA VALVES.

STATIONARY SPINDLES AND HAND WHEELS. FLANGE TOPS. GAS METAL SEATS.

PRINCIPAL DIMENSIONS.

Diameter of Opening, inches,	2½	3	3½	4	5	6	7	8	10	12	14	16	18	20	24
Face to Face, Screw Ends,	6⅝	7½	8⅜	9⅝	10¼	11⅜	12⅛	12½							
Face to Face, Flange Ends,	7⅞	8½	8⅞	9¼	9⅝	10⅛	11½	10¾	12⅛	12½	14	16⅜	18	19	20
Diameter of Flanges,	7	7	8½	9	10	11	12	13	16	18	21	23	25	27	31
Height of Valve, Center of Pipe to Top of Wheel,	10¼	11¾	12¼	17¼	16	19	22½	21⅞	27½	31⅝	35¾	38⅞	44¼	46¾	53⅝
Diameter of Wheel,	5⅞	6⅞	7¾	8½	10	12	12¾	14	15	16	17	18	20	22	24

UNLESS OTHERWISE ORDERED,

These Valves will be Furnished with Stationary Spindles and Hand Wheels, and open by Turning to the Left.

CHAPMAN VALVE MFG. CO.

IRON BODY GAS GATES.

BOLTED TOP. BELL OR SPIGOT ENDS.

Sizes, 2 to 48 inches, inclusive.

IRON BODY GAS GATES.

BOLTED TOP. BELL OR SPIGOT ENDS.

For Street Mains.

These Valves are made with Cast Iron Bodies, Caps, Plugs and Nuts, and Wrought Iron Spindle (tinned) and Gas Metal Seats. They are especially designed for use on Street Mains, and have never failed to give satisfaction. The Gas Metal Seats resist all corrosive influences of the gas, and the seats and faces of the plug never corrode together, but are always clean, open easily and close tightly They are furnished with Bolt Gland Stuffing Boxes; have no gaskets or packing in the flange joints; they are, in every particular, a perfect Gas Gate.

"LONG END" GAS GATES.

This special and valuable feature in Gas Valves is becoming very generally used in the New England States. The Shell is tapped out to receive a pipe to which a gauge may be attached, and thus leaks in the mains are readily detected. We do not list this form of valve, but will cheerfully name prices upon application.

CHAPMAN VALVE MFG. CO.

SPECIAL IRON BODY GAS GATES.

WITH LONG ENDS.

(See description on other side.)

IRON BODY REGULAR BELL END GAS GATES.

FLANGE TOP. GAS METAL SEATS.

PRINCIPAL DIMENSIONS.

Diameter of Opening, inches,	2	3	4	5	6	8	10	12	14	16	18	20	24
End to End of Pipe when laid in Bell,	3⅜	3⅞	4¾	5	5½	6½	7	7⅜	8¼	8⅝	9⅛	10⅛	11⅜
Diameter of Bell Socket,	3⅛	4¾	5¾	7	8	10	12⅛	14½	16¾	18¾	20⅞	23	27
Depth of Bell Socket,	2¾	3½	3½	3¾	4	4¼	4½	4⅝	4¾	5	5	5	6
Height of Gate, center of Pipe to top of Nut,	11⅝	17	18 7/16	17⅜	20 5/16	23¼	28⅝	32⅝	35¾	39¾	48½	49 5/16	56⅜

UNLESS OTHERWISE ORDERED,

Gas Gates with either Bell or Spigot Ends, will have Nut on Spindle and open by Turning to the Left.

CHAPMAN VALVE MFG. CO.

IRON BODY WATER GATES.

COMPOSITION MOUNTINGS. BELL ENDS. BOLTED TOP.

For Street Mains.

IRON BODY WATER GATES.

COMPOSITION MOUNTINGS. BOLTED TOPS. BELL OR SPIGOT ENDS.

Sizes, 2 inches to 48 inches, inclusive.

These Gates are made with Cast Iron Bodies, Caps and Nuts, Composition Spindles, Stuffing Boxes, Glands and Followers; Plugs, Cast Iron, with Composition Faces and Spindle Bushings; Water Metal Seats.

These Gates are more especially for use in Street Mains; they are extra heavy to resist the water hammer and general hard usage to which they are liable. The faces of the plug and seats never corrode, and the gate will, at all times, open easily and close tightly The flanges have no gaskets; bolts are extra heavy, and the spindle large in diameter, of solid composition Gates can be furnished with either Bevel or Upright Gearing, or with Automatic Drips.

CHAPMAN VALVE MFG. CO.

IRON BODY WATER GATES.

COMPOSITION MOUNTINGS. SPIGOT ENDS. BOLTED TOP.

For Street Mains.

IRON BODY BELL END WATER GATES.

FLANGE TOP. WATER METAL SEATS.

PRINCIPAL DIMENSIONS.

Diameter of Opening, inches,	2	3	4	5	6	7	8	10	12	14	15	16	18	20	24
End to End of Pipe when laid in Bell,	3 3/16	3 3/4	5 1/4	5 1/4	6	6	6 3/8	7 5/8	8	10	10	9 7/8	10 7/8	11 1/4	12 1/8
Diameter of Bell Socket,	3 1/8	4 5/8	5 3/4	6 7/8	7 7/8	8 7/8	10	12	14 1/8	16 1/4	17 1/2	18 1/2	20 5/8	22 3/4	26 3/4
Depth of Bell Socket,	2 3/4	2 3/4	3	3	3	3	3	3	3	3 1/4	3 3/8	3 1/2	3 1/2	3 1/2	3 1/2
Height of Gate, center of Pipe to top of Nut,	11 5/8	12 1/4	18 1/4	19 1/4	22	24 1/4	26 1/4	30 7/8	35 3/8	35 3/4	40	41 1/4	48 1/2	50	55 3/8

UNLESS OTHERWISE ORDERED,

All Water Gates will have Nut on Spindle, and open by Turning to the Right.


CHAPMAN
VALVE MFG CO.

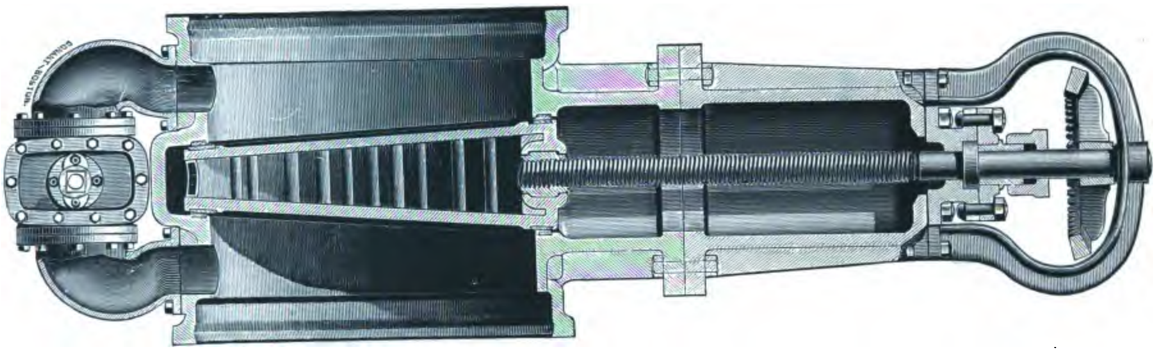
LARGE WATER GATES, WITH GEARING.

WITH OR WITHOUT BY-PASS RELIEF.

While, without question, from manner of construction, the "CHAPMAN" will open and close under any given pressure easier than any other gate, yet, for excessive pressure on large gates, we recommend our By-pass Relief. It is a fact that, in the past experience of water works having heavy pressure, while the smaller gates work comparatively easy, the larger gates, under the excessive load they have to carry, are always a source of no little anxiety when it becomes necessary to open or close them. The only true way to have large gates work easily under heavy pressure is to relieve that pressure during the period of opening or closing. No internal devices of rolls, or other mechanical arrangement, can completely meet the case, or be reliable. Some of our best engineers, for some time past, have constructed by-passes around large gates, by means of a multiplicity of wrought and cast iron fittings, and placing small relief valves in the line of pipe forming the by-pass. This has been a very expensive method, and has been attended with so great inconvenience that it has not given satisfaction. We have, to obviate these difficulties, added to our large gates a large, substantial by-pass (of cast iron), which engages with the body each side of the plug. The size of the by-pass valve is large enough to make a material relief, and is so made and attached to the main gate as to be perfectly interchangeable in all its parts, and all joints are made perfect without the aid of gaskets or packing.


CHAPMAN
VALVE MFG. CO.

LARGE WATER GATES WITH THE BY-PASS RELIEF ATTACHMENT.



These Gates are furnished with or without Gearing. Geared to stand upright or lie on side

Specifications and Prices furnished upon application.

NATURAL GAS VALVES.

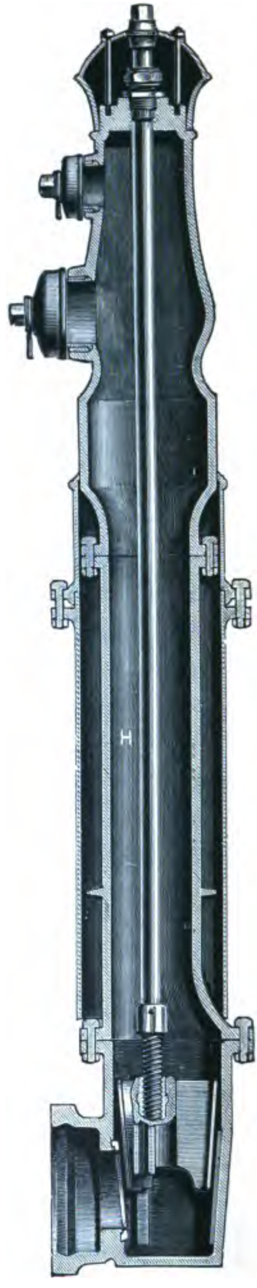
For Light and Heavy Pressure.

During the past few years the fact has been developed that ordinary Valves for this service are both dangerous and expensive, and that to hold and control this extremely volatile and penetrative gas, special Valves and fittings are required.

We have completed patterns for both light and heavy service, from ½ to 10 inches inclusive, both screw and flanged ends. They have been thoroughly tested and pronounced to be the only Valves that have filled the requirements.

As these are a special line of goods, prices, dimensions and testimonials will be furnished upon application.


BOSTON
CONANT BOSTON

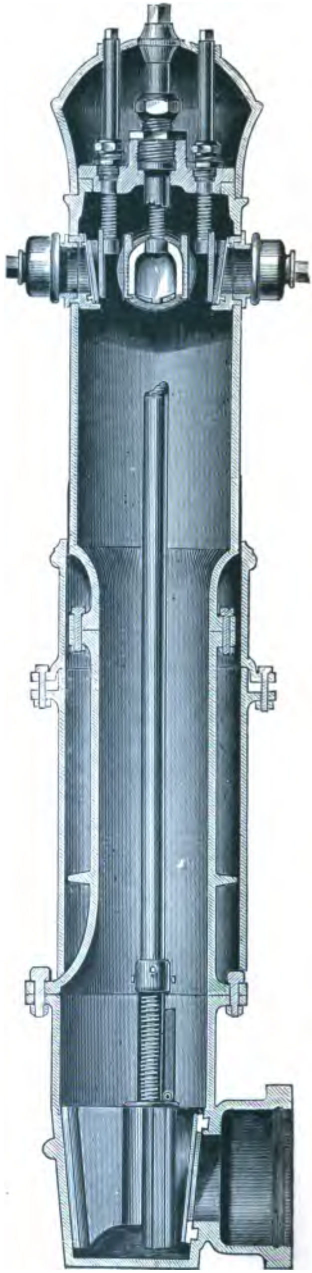


DESCRIPTION OF CHAPMAN FIRE HYDRANTS.

The Chapman Fire Hydrant is of the kind known as the Gate Hydrant. In its design and construction great care has been taken to produce a Hydrant that will perform its service without getting out of order, that will close tightly and remain tight, even in muddy or gritty water, that will open and close easily at all times, and produce no water hammer or strain upon the pipe and joints in closing. The Gate rises upon the Spindle, in opening, into a recess below the Hydrant pipe, large enough to admit the full passage of water from the main, and closes vertically, gradually cutting off the flow of water and preventing any water hammer or strain upon the pipe. The Gate is tapering upon its face, with a tapering pressure-bar on the back, which acts as a wedge to force the Gate to its Seats in closing, and is guided upon its sides to prevent its turning or coming in contact with its Seats until the passage is closed.

The Seats of the Gate and pressure-bar are of Babbitt Metal. The drip outlet, bushed with *Brass,* is constructed in the side of the valve on a level with the water in the main, and is opened and closed by the direct action of the Gate, without intermediate mechanism. It is so arranged that the moment the gate commences to rise, the drip outlet is sealed, and remains sealed until the gate is closed. The drip being always open when the Gate is closed, there is *no liability of freezing.*

The wedge form of the Gate and its non-cohesion to the Babbitt Metal Seats renders this Hydrant easy of operation in opening and closing, irrespective of the length of time it may have been closed. The superior points of merit in the " CHAPMAN " over other hydrants are design, workmanship, material, interchangeability of parts, ease of manipulation under any pressure, no water hammer, a perfect drip, durability and reliability. The cost of maintenance of the Chapman Hydrant we will guarantee to be less than any other Hydrant in the market. The large and increasing demand from all parts of the country for these Hydrants attest the truth of our claim. Abundant testimonials can be furnished.



THE

CHAPMAN FIRE HYDRANT

WITH

INDEPENDENT VALVES

FOR

EACH HOSE NOZZLE.

FOR USE IN

CITIES,

PUBLIC SQUARES,

MILL YARDS, ETC.

CHAPMAN GATE FIRE HYDRANT.

WITH INDEPENDENT VALVES FOR EACH OUTLET OR HOSE NOZZLE.

We have introduced this Hydrant to meet the growing demand for a Hydrant from which a large number of streams can be taken and *concentrated on a fire at any one point,* and yet have each stream under as perfect control as though they were taken from single or separate Hydrants. This we accomplish by placing Independent Valves for each outlet on the inside of the post, each valve being operated by a spindle from the outside, independently of the other valves, and of the main valve at the bottom of the Hydrant. The superiority of this Hydrant over other independent valve hydrants, lies in the *principle of construction, perfection of workmanship, and interchangeability of the parts.*

Each valve is perfect in itself and does not depend on the pressure of water to bring it to its seat. All parts are made by steel templates and gauges, and they can be freely interchanged without impairing the perfection of the Hydrants.

These Hydrants are made with two or more nozzles, a large diameter of post, and with Bell End for either 6 in. or 8 in. connecting pipe.

In ordering Hydrants be particular and give full details. Send coupling or nozzle cap for gauge of threads.

CHAPMAN VALVE MFG. CO.

FIRE HYDRANT.

WITH INDEPENDENT VALVES AT STEAMER OUTLETS.

CHAPMAN GATE FIRE HYDRANT.

WITH INDEPENDENT VALVES FOR STEAMER OUTLETS.

On account of the growing demand for a Hydrant with Independent Valves at Steamer Outlets, we have completed patterns for such, and are now prepared to furnish hydrants with one or two steamer outlets, and, if desired, one or two hose outlets may be placed upon same hydrant, all having independent valves. This, however, at present applies only to our 6 inch hydrants.

POST HYDRANTS.

PRINCIPAL DIMENSIONS.

SIZE. Inches, . .	3	4	5	6
Diameter of Inlet, . .	3	4	5	6
Area of Inlet, . .	$7\frac{7}{100}$	$12\frac{56}{100}$	$19\frac{64}{100}$	$28\frac{27}{100}$
Smallest Diameter of Post,	$3\frac{1}{4}$	$4\frac{1}{4}$	$5\frac{1}{4}$	$6\frac{1}{4}$
Area of Post, . .	$8\frac{30}{100}$	$14\frac{19}{100}$	$21\frac{65}{100}$	$30\frac{68}{100}$
Height Above Pavement, .	$26\frac{1}{2}$	$29\frac{1}{4}$	30	32

Size of Connecting Pipe, 3 inches to 8 inches.

Kind of Connection, either Bell, Spigot, Flange or Screw.

Area of 1-$2\frac{1}{2}$ inch Hose Nozzle, . .	$4\frac{91}{100}$	square inch.
" 2-$2\frac{1}{2}$ " " " . .	$9\frac{82}{100}$	" "
" 3-$2\frac{1}{2}$ " " " . .	$14\frac{73}{100}$	" "
" 4-$2\frac{1}{2}$ " " " . .	$19\frac{64}{100}$	" "
" 1-4 " Steamer Nozzle, .	$12\frac{57}{100}$	" "
" 2-4 " " " .	$25\frac{14}{100}$	" "
" 1-$2\frac{1}{2}$ and 1-4 inch Nozzle, .	$17\frac{48}{100}$	" "
" 2-$2\frac{1}{2}$ " 1-4 " " .	$22\frac{39}{100}$	" "
" 3-$2\frac{1}{2}$ " 1-4 " " .	$27\frac{30}{100}$	" "

Besides the various kinds, styles and sizes of Valves, Gates and Hydrants briefly described in the previous pages, we make many special and peculiar kinds of valves to meet the requirements of our individual customers, and if any one wishes a valve or hydrant that has not been mentioned, and will write us just what he wants, we may have patterns that will suit or we will cheerfully make an estimate of the cost of his special work.

Our aim is to keep an ample stock of all goods for which there is liable to be a demand, and to be ready at all times, to make anything that our customers may desire.

Our Valves and Hydrants are so well and favorably known, that we do not print any testimonials, but if interested parties desire, we will send them copies of voluntary testimonials that we have, or will refer them to such of our customers as are in their vicinity; and we feel confident in saying that no party who uses the Chapman Valves, Gates or Hydrants, will say that they are not *the best* for all uses for which they are intended.

AN ENGINEERING APPENDIX.

INDEX TO ENGINEERING MATTER.

AN

ENGINEERING APPENDIX

Containing useful rules, tables and information, compiled from standard authorities, and presented by the

CHAPMAN VALVE MF'G' CO.,

to their friends, customers and the engineering fraternity in general.

PART I.
General Engineering Data.

PART II.
Hydrodynamics.

PART III.
Steam.

PART IV.
Gas.

In the preparation of this compilation the following authorities have been consulted, the matter is used by permission, and the authors name is attached to everything which is not either common property or the work of the compiler.

A MANUAL OF RULES, TABLES AND DATA,
for Mechanical Engineers, by
Daniel Kinnear Clark, C. E.
London, 1884—Blackie & Son—Old Bailey, E. C.

THE CIVIL ENGINEERS POCKET BOOK.
John C. Trautwine, C. E.
New York—John Wiley & Sons—15 Astor Place.

HYDRAULICS.
The flow of water through orifices over weirs, and through open conduits and pipes.
Hamilton Smith Jr., C. E.
New York—John Wiley & Sons—15 Astor Place.

THE MATERIALS OF ENGINEERING,
In Three Parts.
ROBERT H. THURSTON, A. M. C. E.
New York — John Wiley & Sons — 15 Astor Place.

HYDRAULIC AND WATER SUPPLY ENGINEERING.
JOHN T. FANNING, C. E.
New York — Est. of D. Van Nostrand — 23 Murray St.

A MANUAL OF HEATING AND VENTILATION
F. SCHUMANN, C. E.
New York — Est. of D. Van Nostrand — 23 Murray St.

HYDRAULIC TABLES.
P. J. FLYNN, C. E.
Van Nostrand's Science Series No.

WATER SUPPLY,
From a chemical and sanitary stand-point.
PROF. WM. RIPLEY NICHOLS.
New York — John Wiley & Sons — 15 Astor Place.

STEAM MAKING OR BOILER PRACTICE.
PROF. CHAS. A. SMITH.
The American Engineer, Chicago, Ill.

THE SEPARATE SYSTEM OF SEWERAGE.
STALEY & PIERSON.
New York — Est. of D. Van Nostrand — 23 Murray St.

HEAT CONSIDERED AS A MODE OF MOTION.
JOHN TYNDALL, L. L. D. F. R. S.
New York — D. Appleton & Co. — Broadway.

HYDRAULIC TABLES AND GENERAL INFORMATION RELATING TO WATER WORKS
HOWLAND & ELLIS.
71 Equitable Building, Boston, Mass.

WEIGHTS AND MEASURES.

The origin of English measures is the grain of corn. Thirty-two grains of wheat, dried and gathered from the middle of the ear, weighed what was called one pennyweight; 20 pennyweights were called one ounce, and 20 ounces one pound. Subsequently the pennyweight was divided into 24 grains.

Troy weight was afterwards introduced, by William the Conqueror, from Troyes, in France; but it gave dissatisfaction, as the troy pound did not weigh as much as the pound then in use; consequently a mean weight was established, making 16 ounces equal to one pound and called avoirdupois.

Three grains of barleycorn well dried, placed end to end, made an inch—the basis of length. The length of the arm of King Henry I was made the length of the ulna, or ell which answers to the modern yard.

D. K. CLARK, Rules, Tables and Data.

The standard measure of length of both Great Britain and the United States is in theory, that of a pendulum vibrating seconds at the level of the sea, in the latitude of London, in a vacuum, with Fahrenheit's thermometer at 62°. The length of such a pendulum is supposed to be divided into 39.1393 equal parts called inches, and 36 of these inches were adopted as the standard yard of both countries.

J. C. TRAUTWINE, Engineers Pocket Book.

TROY WEIGHT.

24 grains	1 pennyweight: dwt.
20 pennyweights	1 ounce = 480 grains.
12 ounces	1 pound = 240 dwts. = 5760 grains.

AVOIRDUPOIS OR COMMERCIAL WEIGHT.

27.34375 grains	1 drachm.
16 drachms	1 ounce = 437.5 grains.
16 ounces	1 pound = 256 drachms = 7000 grains
28 pounds	1 quarter = 448 ounces.
4 quarters	1 cwt. = 112 lbs.
20 cwts.	1 ton = 80 quarters = 2240 lbs.

APOTHECARIES WEIGHT.

20 grains	1 scruple	8 drachms	1 ounce
3 scruples	1 drachm	12 ounces	1 pound.

The grain in each of the foregoing tables is the same.

An avoirdupois pound of pure water has the following volumes.

At 32° F.	= .016021 cu. ft.	or 27.684 cu. ins.
39.1° "	= .016019 " "	" 27.680 " "
62° "	= .016037 " "	" 27.712 " "
212° "	= .016770 " "	" 28.978 " "

D. K. CLARK. Rules, Tables, and Data.

TABLE FOR CONVERTING POUNDS TO GROSS TONS.

MR. R. C. P. COGGESHALL, Supt. Water Works, New Bedford, Mass.

Pounds.	Gross Tons.	Pounds.	Gross Tons.	Pounds.	Gross Tons.	Pounds.	Gross Tons.	Pounds.	Gross Tons.
1	.00045	10	.0045	100	.0446	1,000	.4464	10,000	4.4643
2	.0009	20	.0089	200	.0893	2,000	.8929	20,000	8.9286
3	.0013	30	.0134	300	.1339	3,000	1.3393	30,000	13.3929
4	.0018	40	.0179	400	.1786	4,000	1.7857	40,000	17.8572
5	0022	50	.0223	500	.2232	5,000	2.2321	50,000	22.3215
6	.0027	60	.0268	600	.2679	6,000	2.6786	60,000	26.7858
7	.0031	70	.0312	700	.3125	7,000	3.1250	70,000	31.2501
8	.0036	80	.0357	800	.3571	8,000	3.5714	80,000	35.7144
9	.0040	90	.0402	900	.4018	9,000	4.0179	90,000	40.1787
10	.0045	100	.0446	1,000	.4464	10,000	4.4643	100,000	44.6430

For example, how many tons in 275,846 pounds?

200,000	89.286
70,000	31.2501
5,000	2.2321
800	.3571
40	.0179
6	.0027
	123.1459 gross tons.

Long Measure.

By law the U. S. standards of length and weight are made equal to the British.

12 inches	1 foot
3 feet	1 yard = 36 ins. = .9143919 metre.
5½ yards	1 rod, pole or perch = 16½ feet.
40 rods	1 furlong
8 furlongs	1 mile = 5280 feet =63360 ins.
3 miles	1 league.

A palm = 3 ins. A hand = 4 ins. A span = 9 ins.

A fathom = 6 ft. A cable's length = 120 fathoms.

A Gunter's chain is 66 ft. long, and 8 Gunter's chains = 1 mile. In the U. S. a nautical mile is 1.15157 times a common mile.

At the equator, 1° of latitude = 68.70 miles.
" latitude 20°, 1° " = 68.78 "
" " 40°, 1° " = 69.00 "
" " 60°, 1° " = 69.23 "
" " 80°, 1° " = 69.39 "
" " 90°, 1° " = 69.41 "

LENGTHS OF A DEGREE OF LONGITUDE IN DIFFERENT LATITUDES, AT SEA LEVEL.

Deg. of Latit'e.	Miles.	Deg. of Latit'e.	Miles.	Deg. of Latit'e.	Miles.	Deg. of Latit'e.	Miles.
0	69.16	26	62.20	52	42.67	78	14.42
2	69.12	28	61.11	54	40.74	80	12.05
4	68.99	30	59.94	56	38.76	82	9.66
6	68.78	32	58.76	58	36.74		
8	68.49	34	57.39	60	34.67		
10	68.12	36	56.01	62	32.55		
12	67.66	38	54.56	64	30.40		
14	67.12	40	53.05	66	28.21		
16	66.50	42	51.47	68	25.98		
18	65.80	44	49.83	70	23.72		
20	65.02	46	48.12	72	21.43		
22	64.15	48	46.36	74	19.12		
24	63.21	50	44.54	76	16.78		

Table of Degree of Longitude Trautwine.

INCHES AND THEIR EQUIVALENT DECIMAL VALUES IN PARTS OF A FOOT.

Inches.	Fraction of Foot.	Decimal Part of Foot.
1	1/12	.0833
2	1/6	.1667
3	1/4	.25
4	1/3	.3333
5	5/12	.4167
6	1/2	.5
7	7/12	.5833
8	2/3	.6667
9	3/4	.75
10	5/6	.8333
11	11/12	.9167
12	1	1.0

D. K. CLARK, Rules, Tables and Data.

FRACTIONAL PARTS OF AN INCH AND THEIR EQUIVALENT DECIMAL VALUES IN PARTS OF A FOOT.

Fractions of an Inch.	Decimals of Foot	Fractions of an Inch.	Decimals of Foot.
1/16	.0052	9/16	.0469
1/8	.0104	5/8	.0521
3/16	.0156	11/16	.0573
1/4	.0208	3/4	.0625
5/16	.0260	13/16	.0677
3/8	.0313	7/8	.0729
7/16	.0365	15/16	.0781
1/2	.0417	1	.0833

Arranged from Trautwine.

Square or Land Measure.

144 sq. ins.	=	1 sq. foot
9 sq. ft.	=	1 sq. yard
30¼ sq. yds.	=	1 sq. rod
40 sq. rds.	=	1 rood
4 roods	=	1 acre = 43560 sq. ft.

In the U. S. surveys a SECTION OF LAND is 1 mile square, or 640 acres.

A square acre is 208.71 feet on each side.

A circular acre is 235.504 feet in diameter.

Cubic or Solid Measure.

1728 cubic inches	=	1 cubic foot
27 cubic feet	=	1 cubic yard.

A cord of wood being 4 × 4 × 8 ft. contains 128 cu. ft. A ton, 2240 lbs. of Penn. anthracite coal in size for domestic use occupies from 41 to 43 cu. ft.; bituminous coal 44 to 48 cu. ft.; coke, 80 cu. ft.

Liquid Measure.

4 gills	=	1 pint
2 pints	=	1 quart
4 quarts	=	1 gallon = 231 cubic inches.

A cylinder 3½ inches in diam. and 6 inches high will hold almost exactly one quart, and one 7 inches in diam. and 6 inches high will hold very nearly one gallon.

This U. S. gallon is only .8333 of the British imperial gallon. A cubic foot contains about 7½ U. S. gallons.

Dry Measure.

2 pints	=	1 quart
8 quarts	=	1 peck
4 pecks	=	1 bushel.

Four quarts in dry measure contain 268.8 cubic inches, or .96945 of the British imperial gallon. The flour barrel should contain 3.75 cu. ft. and 196 lbs.

The Metric Standards of Weights and Measures.

The primary metric standards are:—the metre, the unit of length; and the kilogramme, the unit of weight, derived from the metre; being the two platinum standards deposited at the Palais des Archives at Paris.

The standard metre is defined to be equal to one ten millionth part of the quadrant of the terrestial meridian passing through Paris, which, by the latest and most authoritative measurement, is 39.3762 inches in terms of the Imperial (British) Standard at 62° F. By the latest and most accurate measurements, the actual standard metre at 32° F. is, in terms of the Imperial Standard, at 62° F. 39.37043 inches; and its legal equivalent declared in the Metric Act of 1864, is 39.3708 inches, being the same as that adopted in France.

The standard kilogramme (1000 grammes) is defined to be the weight of a cubic decimetre of distilled water at its maximum density, at 4°. C or 39.1° F. This is legally, 2.20462125 pounds
or 2 lbs. 3 oz. 4.383 drachms
or 15432.34874 grains.

There is in the Standard Department at Westminster (London) a newly constructed sub-divided standard yard laid down upon a bar of Baily's metal, upon which a sub-divided metre has also been laid down.

The metric unit of capacity is the litre, defined to be equal to a cubic decimetre. Its imperial equivalent is 0.22009 gallon. There is no other official standard of weight and measure in France than the metre and the kilogramme; there is no standard litre or unit of capacity.

The metric system is not really founded on the length of a quadrant of the meridan, and although it is described as a scientific system because of the simple and definite relation between the metre, which is its basis and unit of length, and the kilogramme and litre, which are the units of weights and capacity, it is admitted that it has been found impossible practically to carry it out with scientific accuracy. The standard kilogramme is admitted *not* to be actually the weight of a cubic decimetre of pure water at the specified temperature, nor the litre a measure of capacity holding a cubic decimetre of pure water. The real standard of unit of weight is declared, even by men of science in France, to be merely the platinum kilogramme weight deposited at the Palais des Archives, as the real standard unit and basis of the metric system is the platinum metre also deposited there. It is an accomplished fact however, that all civilized nations have tacitly agreed to recognize the metric system as affording for the future, the advantages of a universal system of weights and measures, and to adopt the standards deposited at the Palais des Archives as the primary units of the system.

From D. K. Clark's Rules, Tables, and Data.

Metric Measures of Length.

10 millimetres	=	1 centimetre
10 centimetres	=	1 decimetre
10 decimetres 100 centimetres 1000 millimetres	=	1 Metre
10 metres	=	1 decametre
10 decametres	=	1 hectometre
10 hectometres	=	1 Kilometre
10 kilometres	=	1 myriametre

A table of Metric Measures of Surface is obtained from the foregoing table by squaring the numbers, and placing the word "square" before each of the names, thus 100 square millimetres = 1 sq. centimetre, and A Table for Volumes is obtained by cubing the numbers, and placing the word "cubic" before the names, thus, 1000 cubic millimetres = 1 cu. centimeter.

For Measures of Capacity the unit is the litre and the table is

10 centilitres	=	1 decilitre
10 decilitres	=	1 Litre
10 litres	=	1 decalitre

and a litre contains 1 cubic decimeter. This portion of the capacity table belongs especially to the measurement of liquids.

For Dry Measures the table is continued and we have

10 litres	=	1 decalitre
10 decalitres or 100 litres	=	1 hectolitre
10 hectolitres or 1000 litres	=	1 kilolitre = 1 cu. metre.

Metric Measures of Weight.

10 milligrammes	=	1 centigrammes
10 centigrammes	=	1 decigramme
10 decigrammes	=	1 Gramme
10 grammes	=	1 decagramme
10 decagrammes	=	1 hectogramme
10 hectogrammes = or 1000 grammes	=	1 Kilogramme
10 kilogrammes	=	1 myriagramme
10 myriagrammes 100 kilogrammes	=	1 quintal metrigue
10 quintaux 1000 kilogrammes	=	1 millier or tonne.

A millier or tonne is the weight of 1 cubic metre of water at 39.1° F.

TABLE FOR FACILITATING APPROXIMATE CALCULATIONS FROM THE METRIC TO THE ENGLISH SYSTEM OF WEIGHTS AND MEASURES.

Feet.	Metres.	Pounds Avoirdupois	Kilogram's.	U. S Gallons.	Imperial Gallons.	Litres.	Cubic Metres.
1	0.30	1	0.45	1	0.83	3.79	0.0038
2	0.61	2	0.91	2	1.67	7.57	0.0076
3	0.91	3	1.36	3	2.50	11.36	0.0114
4	1.22	4	1.81	4	3.33	15.14	0.0151
5	1.52	5	2.26	5	4.17	18.93	0.0189
6	1.83	6	2.72	6	5.00	22.71	0.0227
7	2.13	7	3.18	7	5.83	26.50	0.0265
8	2.44	8	3.62	8	6.66	30.38	0.0303
9	2.74	9	4.08	9	7.50	34.07	0.0341
3.28	1	2.20	1	1.20	1	4.54	0.0045
6.56	2	4.41	2	2.40	2	9.08	0.0091
9.84	3	6.61	3	3.60	3	13.63	0.0136
13.12	4	8.82	4	4.80	4	18.17	0.0182
16.40	5	11.02	5	6.00	5	22.71	0.0227
19.69	6	13.23	6	7.20	6	27.26	0.0273
22.97	7	15.43	7	8.40	7	31.80	0.0318
26.25	8	17.64	8	9.60	8	36.34	0.0363
29.53	9	19.84	9	10.80	9	40.89	0.0409
Miles.	Kilometres.	Kilometres.	Miles.				
1	1.61	1	0.62	0.26	0.22	1	0.001
2	3.22	2	1.24	0.53	0.44	2	0.002
3	4.83	3	1.86	0.79	0.66	3	0.003
4	6.44	4	2.49	1.05	0.88	4	0.004
5	8.05	5	3.11	1.32	1.10	5	0.005
6	9.66	6	3.73	1.58	1.32	6	0.006
7	11.27	7	4.35	1.85	1.54	7	0.007
8	12.87	8	4.97	2.11	1.76	8	0.008
9	14.48	9	5.59	2.38	1.98	9	0.009

From "Water Supply from a Chemical standpoint,"
by PROF. WM. RIPLEY NICHOLS.

MENSURATION.

MENSURATION OF SURFACES.

Area of any parallelogram..	=	base × perpendicular height.
Area of any triangle	=	base × ½ perpendicular height.
Area of any circle..........	=	diameter^2 × .7854
Area of sector of circle	=	arc × ½ radius.
Area of segment of circle...	=	area of sector of equal radius, less area of triangle.
Area of parabola	=	base × 2-3 height.
Area of ellipse..............	=	longest diameter × shortest diameter × .7854
Area of cycloid.............	=	area of generating circle × 3.
Area of any regular polygon	=	sum of its sides × perpendicular from its centre to one of its sides ÷ 2.
Surface of cylinder	=	area of both ends + length × circumference.
Surface of cone.............	=	area of base + circumference of base × ½ slant height.
Surface of sphere...........	=	diameter^2 × 3.1415
Surface of frustum.	=	sum of girt at both ends × ½ slant height + area of both ends
Surface of cylindrical ring..	=	thickness of ring added to the inner diameter × by the thickness × 9.8698
Surface of segment.........	=	height of segment × by whole circumference of sphere of which it is a part.

POLYGONS.

1. To find the area of any regular polygon. Square one of its sides, and multiply said square by the number in 1st column of the following table.

2. Having a side of a regular polygon, to find the radius of a circumscribing circle. Multiply the side by the corresponding number in the 2d column.

3. Having the radius of a circumscribing circle, to find the side of the inscribed regular polygon. Multiply the radius by the corresponding number in 3d column.

Number of Sides.	Name of Polygon.	1 Area =S^2 ×	2 Radius =S ×	3 Side =R ×	Angle contained between two sides.
3	Equilaterial triangle	.433	.5774	1.732	60°
4	Square	1.	.7071	1.4142	90°
5	Pentagon	1.7205	.8507	1.1756	108°
6	Hexagon	2.5891	1.	1.	120°
7	Heptagon	3.6339	1.1524	.8678	128.57°
8	Octagon	4.8284	1.3066	.7654	135°
9	Nonagon	6.1818	1.4619	.684	140°
10	Decagon	7.6942	1.618	.618	144°
11	Undecagon	9.3656	1.7747	.5635	147.27°
12	Dodecagon	11.1962	1.9319	.5176	150°

In the heads of the columns in above table, S=side, and R=Radius.

PROPERTIES OF THE CIRCLE.

Diameter × 3.14159 = circumference.
Diameter × .8862 = side of an equal square.
Diameter × .7071 = side of an inscribed square.
Diameter^2 × .7854 = area of circle.
Radius × 6.28318 = circumference.
Circumference ÷ 3.14159 = diameter.

The circle contains a greater area than any plane figure, bounded by an equal perimeter or outline.

The areas of circles are to each other as the squares of their diameters.

Any circle whose diameter is double that of another contains four times the area of the other.

Area of a circle is equal to the area of a triangle whose base equals the circumference, and perpendicular equals the radius.

MENSURATION OF SOLIDS.

Cylinder............. = area of one end × length.
Sphere................ = cube of diameter × .5236
Segment of sphere..... = square root of the height added to three times the square of radius of base × by height and by .5236
Cone or pyramid ...... = area of base × ⅓ perpendicular height
Frustum of a cone..... = product of diameter of both ends + sum of their squares, × perpendicular height × .2618
Frustum of a pyramid = sum of the areas of the two ends + square root of their product, × by ⅓ of the perpendicular height.
Solidity of a wedge.... = area of base × ½ perpendicular height
Frustum of a wedge... = ½ perpendicular height × sum of the areas of the two ends.
Solidity of a ring...... = thickness + inner diameter, × square of the thickness, × 2.4674

POLYHEDRONS.

No. of Sides.	Name.	1 Radius of Circumscribed Circle. R=S ×	2 Radius of Inscribed Circle. R=S ×	3 Area of Surface. A=S^2 ×	4 Cubic Contents. C=S^3 ×
4	Tetrahedron	.6124	.2041	1.7320	.1178
6	Hexahedron	.866	.5	6.	1.
8	Octahedron	.7071	.4082	3.4641	.4714
12	Dodecahedron	1.4012	1.1135	20.6458	7.6631
20	Icosahedron	.951	.7558	86.602	2.1817

Side is length of linear edge of any side of the figure.

1 — Radius of Circumscribed Circle = *Side* multiplied by the number in 1st column corresponding to figure.

2 — Radius of Inscribed Circle = *Side* multiplied by the number in 2d column corresponding to figure.

3 — Area of Surface = Square of *side* multiplied by the number in 3d column corresponding to figure.

4 — Cubic Contents = Cube of *side* multiplied by number in 4th column corresponding to figure.

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
1-32	.0981	.00076	7½	23.56	44.178	16	50.26	201.06
1-16	.1963	.00306		23.95	45.663		50.65	204.21
1-8	.3926	.01227	7¾	24.34	47.173	16¼	51.05	207.39
3-16	.5890	.02761		24.74	48.707		51.44	210 59
1-4	.7854	.04908	8	25.13	50.265	16½	51.83	213.82
5-16	.9817	.07669		25.52	51.848		52.22	217.07
3-8	1.178	.1104	8¼	25.91	53.456	16¾	52.62	220.35
7-16	1.374	.1503		26.31	55.088		53.01	223.65
1-2	1.570	.1963	8½	26.70	56.745	17	53.40	226.98
9-16	1.767	.2485		27.09	58.426		53.79	230.33
5-8	1.963	.3097	8¾	27.48	60.132	17¼	54.19	233.70
11-16	2.159	.3712		27.88	61.862		54.58	237.10
3-4	2 356	.4417	9	28.27	63,617	17½	54.97	240.52
13-16	2.552	.5184		28.66	65.396		55.37	243.97
7-8	2.748	.6013	9¼	29.05	67.200	17¾	55.76	247.45
15-16	2 945	.6902		29.45	69 029		56.16	250.94
1	3.141	.7854	9½	29.84	70.882	18	56.54	254.46
	3.534	.9940		30.23	72.759		56.94	258.01
1¼	3.927	1.227	9¾	30 63	74.662	18¼	57.33	261.58
	4.319	1.484		31.02	76.588		57.72	265.18
1½	4.712	1.767	10	31.41	78.539	18½	58.11	268.80
	5.105	2.073		31.80	80 515		58.51	272.44
1¾	5.497	2.405	10¼	32.20	82.516	18¾	58.90	276.11
	5.890	2.761		32.59	84.540		59.29	279.81
2	6.283	3.141	10½	32.98	86.590	19	59.69	283.52
	6.675	3.546		33.37	88.664		60.08	287.27
2¼	7.068	3.976	10¾	33.77	90.762	19¼	60.47	291.03
	7.461	4.430		34.16	92 885		60.86	294.83
2½	7.854	4.908	11	34.55	95.033	19½	61.26	298.64
	8.246	5.411		34.95	97.205		61.65	302.48
2¾	8.639	5.939	11¼	35.34	99.402	19¾	62.04	306.35
	9.032	6.491		35.73	101.62		62.43	310.24
3	9.424	7.068	11½	36.12	103.86	20	62.83	314.16
	9.817	7.669		36.52	106.13		63.22	318.09
3¼	10.21	8.295	11¾	36.91	108.43	20¼	63.61	322.06
	10.60	8.946		37.30	110.75		64.01	326.05
3½	10.99	9.621	12	37.69	113.09	20½	64.40	330.06
	11.38	10.320		38.09	115.46		64.79	334.10
3¾	11.78	11.044	12¼	38.48	117.85	20¾	65.18	338.16
	12.17	11.793		38.87	120.27		65.58	342.25
4	12 56	12 566	12½	39.27	122.71	21	65.97	346.36
	12.95	13.364		39.66	125.18		66.36	350.49
4¼	13.35	14.186	12¾	40.05	127.67	21¼	66.75	354.65
	13.74	15.033		40.44	130.19		67.15	358.84
4½	14.13	15.904	13	40.84	132.73	21½	67.54	363.05
	14.52	16.800		41.23	135.29		67.93	367.28
4¾	14.92	17.720	13¼	41.62	137.88	21¾	68.32	371.54
	15.31	18.665		42.01	140.50		68.72	375.82
5	15.70	19.635	13½	42.41	143.13	22	69.11	380.13
	16.10	20 629		42.80	145.80		69.50	384.46
5¼	16.49	21 647	13¾	43.19	148.48	22¼	69.90	388.82
	16.88	22.690		43.58	151.20		70.29	393.20
5½	17.27	23.758	14	43.98	153.93	22½	70.68	397.60
	17.67	24.850		44.37	156.69		71.07	402.03
5¾	18.06	25.967	14¼	44.76	159.48	22¾	71.47	406.49
	18.45	27.108		45.16	162.29		71.86	410.97
6	18.84	28.274	14½	45.55	165.13	23	72.25	415.47
	19.24	29.464		45.94	167.98		72.64	420.00
6¼	19.63	30.679	14¾	46.33	170.87	23¼	73.04	424.55
	20.02	31.919		46.73	173.78		73.43	429.13
6½	20.42	33.183	15	47.12	176.71	23½	73.82	433.73
	20.81	34.471		47.51	179.67		74.21	438.30
6¾	21.20	35.784	15¼	47.90	182.65	23¾	74.61	443.01
	21.57	37.122		48.30	185.66		75.00	447.69
7	21.99	38.484	15½	48.69	188.69	24	75.39	452.39
	22.38	39.871		49.08	191.74		75.79	457.11
7¼	22.77	41.282	15¾	49.48	194.82	24¼	76.18	461.86
	23.16	42.718		49.87	197.93		76.57	466.63

CIRCUMFERENCES AND AREAS OF CIRCLES—Continued.

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
24½ —	76.96	471.43	33 —	103.6	855.30	41½ —	130.3	1352.6
	77.36	476.25		104.0	861.79		130.7	1360.8
24¾ -	77.75	481.10	33¼ -	104.4	868.30	41¾ -	131.1	1369.0
	78.14	485.97		104.8	874.88		131.5	1377.2
25 —	78.54	490.87	33½ —	105.2	881.41	42 —	131.9	1385.4
	78.93	495.79		105.6	888.00		132.3	1393.7
25¼ -	79.32	500.74	33¾ -	106.0	894.61	42¼ -	132.7	1401.9
	79.71	505.71		106.4	901.25		133.1	1410.2
25½ .—	80.10	510.70	34 —	106.8	907.92	42½ —	133.5	1418.6
	80.50	515.72		107.2	914.61		133.9	1426.9
25¾ -	80.89	520.70	34¼ -	107.5	921.32	42¾ -	134.3	1435.3
	81.28	525.83		107.9	928.06		134.6	1443.7
26 —	81.68	530.93	34½ —	108.3	934.82	43 —	135.0	1452.2
	82.07	536.04		108.7	941.60		135.4	1460.6
26¼ -	82.46	541.18	34¾ -	109.1	948.41	43¼ -	135.8	1469.1
	82.85	546.35		109.5	955.25		136.2	1477.6
26½ —	83.25	551.54	35 —	109.9	962.11	43½ —	136.6	1486.1
	83.64	556.76		110.3	968.99		137.0	1494.7
26¾ -	84.03	562.00	35¼ -	110.7	975.90	43¾ -	137.4	1503.3
	84.43	567.26		111.1	982.84		137.8	1511.9
27 —	84.82	572.55	35½ —	111.5	989.80	44 —	138.2	1520.5
	85.21	577.87		111.9	996.78		138.6	1529.1
27¼ -	85.60	583.20	35¾ -	112.3	1003.7	44¼ -	139.0	1537.8
	86.00	588.57		112.7	1010.8		139.4	1546.5
27½ —	86.39	593.95	36 —	113.0	1017.8	44½ —	139.8	1555.2
	86.78	599.37		113.4	1024.9		140.1	1564.0
27¾ -	87.17	604.80	36¼ -	113.8	1032.0	44¾ -	140.5	1572.8
	87.57	610.26		114.2	1039.1		140.9	1581.6
28 —	87.96	615.75	36½ —	114.6	1049.3	45 —	141.3	1590.4
	88.35	621.26		115.0	1053.5		141.7	1599.2
28¼ -	88.75	626.79	36¾ -	115.4	1060.7	45¼ -	142.1	1608.1
	89.14	632.35		115.8	1067.9		142.5	1617.0
28½ —	89.53	637.94	37 —	116.2	1075.2	45½ —	142.9	1625.9
	89.92	643.54		116.6	1082.4		143.3	1634.9
28¾ -	90.32	649.18	37¼ -	117.0	1089.7	45¾ -	143.7	1643.8
	90.71	654.83		117.4	1097.1		144.1	1652.8
29 —	91.10	660.52	37½ —	117.8	1104.4	46 —	144.5	1661.9
	91.49	666.22		118.2	1111.8		144.9	1670.9
29¼ -	91.89	671.95	37¾ -	118.6	1119.2	46¼ -	145.2	1680.0
	92.28	677.71		118.9	1126.6		145.6	1689.1
29½ —	92.67	683.49	38 —	119.3	1134.1	46½ —	146.0	1698.2
	93.06	689.29		119.7	1141.5		146.4	1707.3
29¾ -	93.46	695.12	38¼ -	120.1	1149.0	46¾ -	146.8	1716.5
	93.85	700.98		120.5	1156.6		147.2	1725.7
30 —	94.24	706.86	38½ —	120.9	1164.1	47 —	147.6	1734.9
	94.64	712.76		121.3	1171.7		148.0	1744.1
30¼ -	95.03	718.69	38¾ -	121.7	1179.3	47¼ -	148.4	1753.4
	95.42	724.64		122.1	1186.9		148.8	1762.7
30½ —	95.81	730.61	39 —	122.5	1194.5	47½ —	149.2	1772.0
	96.21	736.61		122.9	1202.2		149.6	1781.3
30¾ -	96.60	742.64	39¼ -	123.3	1209.9	47¾ -	150.0	1790.7
	96.99	748.69		123.7	1217.6		150.4	1800.1
31 —	97.38	754.76	37½ —	124.0	1225.4	48 —	150.7	1809.5
	97.78	760.86		124.4	1233.1		150.1	1818.9
31¼ -	98.17	766.99	39¾ -	124.8	1240.9	48¼ -	151.5	1828.4
	98.56	773.14		125.2	1248.7		151.9	1837.9
31½ —	98.96	779.31	40 —	125.6	1256.6	48½ —	152.3	1847.4
	99.35	785.51		126.0	1264.5		152.7	1856.9
31¾ -	99.74	791.73	40¼ -	126.4	1272.3	48¾ -	153.1	1866.5
	100.1	797.97		126.8	1280.3		153.5	1876.1
32 —	100.5	804.24	40½ —	127.2	1288.2	49 —	153.9	1885.7
	100.9	810.54		127.6	1291.2		154.3	1895.3
32¼ -	101.3	816.86	40¾ -	128.0	1304.2	49¼ -	154.7	1905.0
	101.7	823.21		128.4	1312.2		155.1	1914.7
32½ —	102.1	829.57	41 —	128.8	1320.2	49½ —	155.5	1924.4
	102.4	835.97		129.1	1328.3		155.9	1934.1
32¾ -	102.8	842.39	41¼ -	129.5	1336.4	49¾ -	156.2	1943.9
	103.2	848.83		129.9	1344.5		156.6	1953.6

CIRCUMFERENCES AND AREAS OF CIRCLES—Continued.

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
50	157.0	1963.5	58½	183.7	2687.8	67	210.4	3525 6
	157.4	1973.3		184.1	2699.3		210.9	3538.8
50¼	157.8	1983.1	58¾	184.5	2710.8	67¼	211.2	3552.0
	158.2	1993.0		184.9	2722.4		211.6	3565.2
50½	158.6	2002.9	59	185.3	2733.9	67½	212.0	3578.4
	159.0	2012.8		187.1	2745.5		212.4	3591.7
50¾	159.4	2022.8	59¼	186.1	2757.1	67¾	212.8	3605.0
	159.8	2032.8		186.5	2768.8		213.2	3618.3
51	160.2	2042.8	59½	186.9	2780.5	68	213.6	3631.6
	160.6	2052.8		187.3	2792.2		214.0	3645.0
51¼	161.0	2062.9	59¾	187.7	2803.9	68¼	214.4	3658.4
	161.3	2072.9		188.1	2815.6		214.8	3671.8
51½	161.7	2083.0	60	188.4	2827.4	68½	215.1	3685.2
	162.1	2093.2		188.8	2839.2		215.5	3698.7
51¾	162.5	2103.3	60¼	189.2	2851.0	68¾	215.9	3712.2
	162.9	2113.5		189.6	2862 8		216.3	3725.7
52	163.3	2123.7	60½	190.0	2874.7	69	216.7	3739.2
	163.7	2133.9		190.4	2886.6		217.1	3752.8
52¼	164.1	2144.1	60¾	190.8	2898.5	69¼	217.5	3766.4
	164.5	2154.4		191.2	2910.5		217.9	3780 0
52½	164.9	2164.7	61	191.6	2922.4	69½	218.3	3793.6
	165.3	2175.0		192.0	2934.4		218.7	3807.3
52¾	165.7	2185.4	61¼	192.4	2946.4	69¾	219.1	3821.0
	166.1	2195.7		192.8	2958.5		219.5	3834.7
53	166.5	2206.1	61½	193.2	2970.5	70	219.9	3848 4
	166.8	2216.6		193.6	2982.6		220.3	3862.2
53¼	167.2	2227.0	61¾	193.9	2994.7	70¼	220.6	3875.9
	167.6	2237.5		194.3	3006.9		221.0	3889 8
53½	168.0	2248.0	62	194.7	3019.0	70½	221.4	3903.6
	168.4	2258.5		195.1	3031.2		221.8	3917.4
53¾	168.8	2269.0	62¼	195.5	3043.4	70¾	222.2	3931.3
	169.2	2279.6		195.9	3055.7		222 6	3945.2
54	169.6	2290.2	62½	196.3	3067.9	71	223.0	3959.2
	170.0	2300.8		196.7	3080.2		223.4	3973.1
54¼	170.4	2311.4	62¾	197.1	3092.5	71¼	223.8	3987.1
	170.8	2322.1		197.5	3104.8		224.2	4001.1
54½	171.2	2332.8	63	197.9	3117.2	71½	224.6	4015.1
	171.6	2343.5		198.3	3129.6		225.0	4029.2
54¾	172.0	2354.2	63¼	198.7	3142.0	71¾	225 4	4043.2
	172.3	2365.0		199.0	3144.4		225.8	4067.3
55	172.7	2375.8	63½	199.4	3166.9	72	226.1	4071.5
	173.1	2386.6		199.8	3179.4		226.5	4085.6
55¼	173.5	2397.4	63¾	200.2	3191.9	72¼	226.9	4099.8
	173.9	2408.3		200.6	3204.4		227.3	4114 0
55½	174.3	2419.2	64	201.0	3216.9	72½	227.7	4128.2
	174.7	2430.1		201.4	3229 5		228.1	4142 5
55¾	175.1	2441.0	64¼	201.8	3242.1	72¾	228.5	4156.7
	175.5	2452.0		202.2	3254.8		228.9	4171.0
56	175.9	2463.0	64½	202.6	3267.4	73	229.3	4185.3
	176.3	2474.0		203.0	3280.1		229.7	4199.7
56¼	176.7	2485.0	64¾	203.4	3292.8	73¼	230.1	4214.1
	177.1	2496.1		203.8	3305.5		230.5	4228.5
56½	177.5	2507.1	65	204.2	3318.3	73½	230.9	4242.9
	177 8	2518.2		204 5	3331.0		231.3	4257.3
56¾	178.2	2529.4	65¼	204.9	3343.8	73¾	231.6	4271.8
	178.6	2540.5		205.3	3356.7		232.0	4286.3
57	179.0	2551.7	65½	205.7	3369.5	74	232.4	4300.8
	179.4	2562.9		206.1	3382.4		232.8	4315.3
57¼	179.8	2574.1	65¾	206.5	3395.3	74¼	233.2	4329.9
	180 2	2585.4		206.9	3408.2		233.6	4344.5
57½	180.6	2596.7	66	207.3	3421.2	74½	234.0	4359.1
	181.0	2608.0		207.7	3434.1		234.4	4373.8
57¾	181.4	2619.3	66¼	208.1	3447.1	74¾	234.8	4388.4
	181.8	2630.7		208.5	3460.1		235.2	4403.1
58	182.2	2642.0	66½	208.9	3473.2	75	235.6	4417.8
	182.6	2653.4		209.3	3486.3		236.0	4432.6
58¼	182.9	2664.9	66¾	209.7	3499.3	75¼	236.4	4447.3
	183.3	2676.3		210.0	3512.5		236.7	4462.1

CIRCUMFERENCES AND AREAS OF CIRCLES—Concluded.

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
75½ —	237.1	4476.9	84 —	263.8	5541.7	92½ —	290.5	6720.0
	237.5	4491.8		264.2	5558.2		290.9	6738.2
75¾ -	237 9	4506.6	84¼ -	264.6	5574.8	92¾ -	291.3	6756.4
	238.3	4521.5		265.0	5591.3		291.7	6776.4
76 —	238.7	4536.4	84½ —	265.4	5607.9	93 —	292.1	6792.9
	239.1	4551.4		265.8	5624.5		292.5	6811.1
76¼ -	239.5	4566.3	84¾ -	266.2	5641.1	93¼ -	292 9	6829.4
	239.9	4581.3		266.6	5657.8		293.3	6847.8
76½ —	240.3	4596.3	85 —	267.0	5674.5	93½ —	293.7	6866.1
	240.7	4611.3		267.4	5691.2		294.1	6884.5
76¾ -	241.1	4626.4	85¼ -	267.8	5707.9	93¾ -	294.5	6902 9
	241.5	4641.5		268.2	5724.6		294.9	6921.3
77 —	241.9	4656.6	85½ —	269.6	5741.4	94 —	295.3	6939.7
	242.2	4671.7		268 9	5758.2		295.7	6958.2
77¼ -	242.6	4686.9	85¾ -	269.3	5775.0	94¼ -	296.0	6976.7
	243.0	4702.1		269.7	5791.9		296.4	6995.2
77½ —	243.4	4717.3	86 —	270.1	5808.8	94½ —	296 8	7013.8
	243.8	4732.5		270.5	5825.7		297.2	7032.3
77¾ -	244.2	4747.7	86¼ -	270.9	5842.6	94¾ -	297.6	7050.9
	244.6	4763.0		271.3	5859.5		298.0	7069.5
78 —	245.0	4778.3	86½ —	271.7	5876.5	95 —	298.4	7088.2
	245.4	4793.7		272.1	5893.5		298.8	7106.9
78¼ -	245.8	4809.0	86¾ -	272.5	5910.5	95¼ -	299.2	7125.5
	246.2	4824.4		272.9	5927.6		299.6	7144.3
78½ —	246.6	4839.8	87 —	273.3	5944.6	95½ —	300.0	7163 0
	247.0	4855.2		273.7	5961.7		300.4	7181.8
78¾ -	247.4	4870.7	87¼ -	274.1	5978.9	95¾ -	300.8	7200.5
	247.7	4886.1		274.4	5996.0		301.2	7219.4
79 —	248.1	4901.6	87½ —	274.8	6013.2	96 —	301.5	7238.2
	248.5	4917.2		275.2	6030.4		301.9	7257.1
79¼ -	248.9	4932.7	87¾ -	275.6	6047.6	96¼ -	302.3	7275.9
	249.3	4948.3		276.0	6064.8		302.7	7294.9
79½ —	249.7	4963.9	88 —	276.4	6082.1	96½ —	303.1	7313.8
	250.1	4979.5		276.8	6099.4		303.5	7332.8
79¾ -	250.5	4995.1	88¼ -	277.2	6116.7	96¾ -	303.9	7341.7
	250.9	5010 8		277 6	6134.0		304.3	7370.7
80 —	251.3	5026.5	88½ —	278.0	6151.4	97 —	304 7	7389.8
	251.7	5042.2		278.4	6168.8		305.1	7408.8
80¼ -	252.1	5058.0	88¾ -	278.8	6186.2	97¼ -	305.5	7427.9
	252.5	5073.7		279.2	6203.6		305.9	7447.0
80½ —	252.8	5089.5	89 —	279.6	6221.1	97½ —	306.3	7466.2
	253.2	5105.4		279.9	6238.6		306.6	7485.3
80¾ -	253.6	5121.2	89¼ -	280 3	6256.1	97¾ -	307.0	7504.5
	254.0	5137.1		280.7	6273.6		307.4	7523.7
81 —	254.4	5153.0	89½ —	281.1	6291.2	98 —	307.8	7542.9
	254.8	5168.9		281.5	6308.8		308.2	7562.2
81¼ -	255.2	5184.8	89¾ -	281.9	6326.4	98¼ -	308.6	7581.5
	255.6	5200.8		282.3	6344.0		309.0	7600.8
81½ —	256.0	5216.8	90 —	282.7	6361.7	98½ —	309 4	7620.1
	256.4	5232.8		283.1	6379.4		309.8	7639.4
81¾ -	256.8	5248.8	90¼ -	283.5	6397.1	98¾ -	310.2	7658.8
	257.2	5264 9		283.9	6414.8		310.6	7678.2
82 —	257.6	5281.0	90½ —	284.3	6432.6	99 —	311.0	7697.7
	258.0	5297.1		284.7	6450 4		311.4	7717.1
82¼ -	258.3	5313.2	90¾ -	285.1	6468 2	99¼ -	311.8	7736.6
	258.7	5329.4		285.4	6486.0		312.1	7756.1
82½ —	259.1	5345.6	91 —	285.8	6503.8	99½ —	312.5	7775.6
	259.5	5361.8		286.2	6521.7		312.9	7795.2
82¾ -	259 9	5378.0	91¼ -	286.6	6539.6	99¾ -	313 3	7814.7
	260.3	5394.3		287.0	6557.6		313.7	7834.3
83 —	260.7	5410.6	91½ —	287.4	6575.5	100 —	314.1	7853.9
	261.1	5426.9		287.8	6593.5		314.5	7854.0
83¼ -	261.5	5443.2	91¾ -	288.2	6611.5	100¼ -	314 9	7893.3
	261.9	5459.6		288.6	6629.5		315.3	7913.1
83½ —	262.3	5476.0	92 —	289.0	6647.6	100½ —	315.7	7932.7
	262.7	5492.4		289.4	6665.7		316.0	7942.4
83¾ -	263.1	5508.8	92¼ —	289.8	6683 8	100¾ -	316.4	7972.2
	263.5	5525.3		290.2	6701 9		316.8	7991.9

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS FROM .1 TO 20.

No.	Sq.	Cube.	Sq. Rt.	C. Rt.	No.	Sq. Rt.	C. Rt.	No.	Sq. Rt	C. Rt.
.1	.01	.001	.316	.464	.4	2.098	1.639	.5	3.240	2.189
.15	.023	.003	.387	.531	.5	2.121	1.651	.6	3.256	2.197
.2	.04	.008	.447	.585	.6	2.145	1.663	.7	3.271	2.204
.25	.063	.016	.500	.630	.7	2.168	1.675	.8	3.286	2.211
.3	.09	.027	.548	.669	.8	2.191	1.687	.9	3.302	2.217
.35	.123	.043	.592	.705	.9	2.214	1.699	11 0	3.317	2.224
.4	.16	.064	.633	.737	5.0	2.236	1.710	.1	3.332	2.231
.45	.203	.091	.671	.766	.1	2.258	1.721	.2	3.347	2.237
.5	.25	.125	.707	.794	.2	2.280	1.733	.3	3 362	2.244
.55	.303	.166	.742	.819	.3	2.302	1.744	.4	3.376	2.251
.6	.36	.216	.775	.843	.4	2.324	1.754	.5	3.391	2.257
.65	.423	.275	.806	.866	.5	2.345	1.765	.6	3.406	2.264
.7	.49	.343	.837	.888	.6	2.366	1 776	.7	3.421	2.270
.75	.563	.422	.866	.909	.7	2.388	1.786	.8	3.435	2.277
.8	.64	.512	.894	.928	.8	2.408	1.797	.9	3 450	2.283
.85	.723	.614	.922	.947	.9	2.429	1.807	12.0	3.464	2.289
.9	.81	.729	.949	.965	6.0	2.450	1.817	.1	3.479	2.296
.95	.903	.857	.975	.983	.1	2.470	1.827	.2	3.493	2.302
1.	1.000	1.000	1.000	1.000	.2	2.490	1.837	.3	3.507	2.308
.05	1.103	1.158	1.025	1.016	.3	2.510	1.847	.4	3 521	2.315
1.1	1.210	1.331	1.049	1.032	.4	2.530	1.857	.5	3.536	2.321
.15	1.323	1.521	1.072	1.048	.5	2.550	1.866	.6	3.550	2.327
1.2	1.440	1.728	1.095	1.063	.6	2.569	1.876	.7	3.564	2.333
.25	1.563	1.953	1.118	1.077	.7	2.588	1.885	.8	3.578	2 339
1.3	1.690	2.197	1.140	1.091	.8	2.608	1.895	.9	3.592	2.345
.35	1.823	2.460	1.162	1.105	.9	2.627	1.904	13.0	3.606	2.351
1.4	1.960	2,744	1.183	1.119	7.0	2.646	1.913	.2	3.633	2.363
.45	2.103	3 049	1.204	1.132	.1	2 665	1.922	.4	3.661	2.375
1.5	2 250	3 375	1.225	1.145	.2	2.683	1.931	.6	3.688	2.387
.55	2.403	3.724	1.245	1.157	.3	2.702	1.940	.8	3.715	2.399
1.6	2.560	4.096	1.265	1.170	.4	2.720	1.949	14.0	3.742	2 410
.65	2.723	4 492	1.285	1.182	.5	2.739	1.957	.2	3.768	2 422
1.7	2.890	4.913	1.304	1.194	.6	2.757	1.966	.4	3.795	2 433
.75	3.063	5.359	1.323	1.205	.7	2.775	1.975	.6	3.821	2.444
1.8	3.240	5.832	1.342	1.216	.8	2.793	1.983	.8	3.847	2.455
.85	3.423	6.332	1.360	1.228	.9	2.811	1.992	15.0	3.873	2 466
1.9	3.610	6.859	1.378	1.239	8.0	2.828	2.000	.2	3.899	2.477
.95	3.803	7.415	1.396	1.249	.1	2.846	2.008	.4	3.924	2.488
2.0	4.000	8.000	1.414	1.260	.2	2.864	2.017	.6	3.950	2.499
.1	4.410	9 261	1.449	1.281	.3	2.881	2.025	.8	3.975	2.509
.2	4 840	10.65	1.483	1.301	.4	2.898	2.033	16.0	4.000	2.520
.3	5.290	12.17	1.517	1.320	.5	2.916	2.041	.2	4.025	2.530
.4	5.760	13.82	1.549	1.339	.6	2.933	2.049	.4	4.050	2.541
.5	6 250	15.63	1.581	1.357	.7	2.950	2.057	.6	4.074	2 551
.6	6.760	17.58	1.613	1.375	.8	2.967	2.065	.8	4.099	2.561
.7	7.290	19.68	1.643	1.393	.9	2.983	2.072	17.0	4.123	2.571
.8	7.840	21.95	1.673	1.409	9.0	3.000	2.080	.2	4.147	2.581
.9	8.410	24.39	1.703	1.426	.1	3.017	2 088	.4	4.171	2.591
3.0	9.00	27.00	1.732	1.442	.2	3.033	2.095	.6	4.195	2.601
.1	9.61	29.79	1 761	1.458	.3	3.050	2.103	.8	4.219	2.611
.2	10.24	32.77	1.789	1.474	.4	3.066	2.111	18.0	4.243	2 621
.3	10.89	35.94	1.817	1.489	.5	3.082	2.118	.2	4.266	2.630
.4	11.56	39.30	1.844	1.504	.6	3.098	2.125	.4	4.290	2.640
.5	12.25	42.88	1.871	1.518	.7	3.115	2.133	.6	4.313	2.650
.6	12.96	46.66	1.897	1.533	.8	3.131	2.140	.8	4.336	2.659
.7	13.69	50.65	1.924	1.547	.9	3.146	2.147	19.0	4.359	2.668
.8	14.44	54.87	1.949	1.561	10.0	3.162	2.154	.2	4.382	2.678
.9	15.21	59 32	1.975	1.574	.1	3.178	2.162	.4	4.405	2.687
4.0	16.00	64.00	2.000	1.587	.2	3.194	2.169	.6	4.427	2.696
.1	16.81	68.92	2.025	1.601	.3	3.209	2.177	.8	4.450	2.705
.2	17.64	74.09	2.049	1.613	.4	3.225	2.183	20.0	4.472	2.714
.3	18.49	79.51	2 074	1.626						

TABLE OF SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000.

No.	Square	Cube.	Sq. Rt.	C. Rt.	No.	Square.	Cube.	Sq. Rt.	C. Rt.
1	1	1	1.0000	1.0000	61	3721	226981	7.8102	3.9365
2	4	8	1.4142	1.2599	62	3844	238328	7.8740	3.9579
3	9	27	1.7321	1.4422	63	3969	250047	7.9373	3.9791
4	16	64	2.0000	1.5874	64	4096	262144	8.0000	4.0000
5	25	125	2.2361	1.7100	65	4225	274625	8.0623	4.0207
6	36	216	2.4495	1.8171	66	4356	287496	8.1240	4.0412
7	49	343	2.6458	1.9129	67	4489	300764	8.1854	4.0615
8	64	512	2.8284	2.0000	68	4624	314432	8.2462	4.0817
9	81	729	3.0000	2.0801	69	4761	328509	8.3066	4.1016
10	100	1000	3.1623	2.1544	70	4900	343000	8.3666	4.1213
11	121	1331	3.3166	2.2240	71	5041	357911	8.4261	4.1408
12	144	1728	3.4641	2.2894	72	5184	373248	8.4853	4.1602
13	169	2197	3.6056	2.3513	73	5329	389017	8.5440	4.1793
14	196	2744	3.7417	2.4101	74	5476	405224	8.6023	4.1983
15	225	3375	3.8730	2.4662	75	5625	421875	8.6603	4.2172
16	256	4096	4.0000	2.5198	76	5766	438976	8.7178	4.2358
17	289	4913	4.1231	2.5713	77	5929	456533	8.7750	4.2543
18	324	5832	4.2426	2.6207	78	6084	474552	8.8318	4.2727
19	361	6859	4.3589	2.6684	79	6241	493039	8.8882	4.2908
20	400	8000	4.4721	2.7144	80	6400	512000	8.9443	4.3089
21	441	9261	4.5826	2.7589	81	6561	531441	9.0000	4.3267
22	484	10648	4.6904	2.8020	82	6724	551368	9.0554	4.3445
23	529	12167	4.7958	2.8429	83	6889	571787	9.1104	4.3621
24	576	13824	4.8990	2.8845	84	7056	592704	9.1652	4.3795
25	625	15625	5.0000	2.9240	85	7225	614125	9.2195	4.3968
26	676	17576	5.0990	2.9625	86	7396	636056	9.2736	4.4140
27	729	19683	5.1962	3.0000	87	7569	658503	9.3274	4.4310
28	784	21952	5.2915	3.0366	88	7744	681472	9.3808	4.4480
29	841	24389	5.3852	3.0723	89	7921	704969	9.4340	4.4647
30	900	27000	5.4772	3.1072	90	8100	729000	9.4868	4.4814
31	961	29791	5.5678	3.1414	91	8281	753571	9.5394	4.4979
32	1024	32768	5.6569	3.1748	92	8464	778688	9.5917	4.5144
33	1089	35937	5.7446	3.2075	93	8649	804357	9.6437	4.5307
34	1156	39304	5.8310	3.2396	94	8836	830584	9.6954	4.5468
35	1225	42875	5.9161	3.2711	95	9025	857375	9.7468	4.5629
36	1296	46656	6.0000	3.3019	96	9216	884736	9.7980	4.5789
37	1369	50653	6.0828	3.3322	97	9409	912673	9.8489	4.5947
38	1444	54872	6.1644	3.3620	98	9604	941192	9.8995	4.6104
39	1521	59319	6.2450	3.3912	99	9801	970299	9.9499	4.6261
40	1600	64000	6.3246	3.4200	100	10000	1000000	10.0000	4.6416
41	1681	68921	6.4031	3.4482	101	10201	1030301	10.0499	4.6570
42	1764	74088	6.4807	3.4760	102	10404	1061208	10.0995	4.6723
43	1849	79507	6.5574	3.5034	103	10609	1092727	10.1489	4.6875
44	1936	85184	6.6332	3.5303	104	10816	1124864	10.1980	4.7027
45	2025	91125	6.7082	3.5569	105	11025	1157625	10.2470	4.7177
46	2116	97336	6.7823	3.5830	106	11236	1191016	10.2957	4.7326
47	2209	103823	6.8557	3.6088	107	11449	1225043	10.3441	4.7475
48	2304	110592	6.9282	3.6342	108	11664	1259712	10.3923	4.7622
49	2401	117649	7.0000	3.6593	109	11881	1295029	10.4403	4.7769
50	2500	125000	7.0711	3.6840	110	12100	1331000	10.4881	4.7914
51	2601	132651	7.1414	3.7084	111	12321	1367631	10.5357	4.8059
52	2704	140608	7.2111	3.7325	112	12544	1404928	10.5830	4.8203
53	2809	148877	7.2801	3.7563	113	12769	1442897	10.6301	4.8346
54	2916	157464	7.3485	3.7798	114	12996	1481544	10.6771	4.8488
55	3025	166375	7.4162	3.8030	115	13225	1520875	10.7238	4.8629
56	3136	175616	7.4833	3.8259	116	13456	1560896	10.7703	4.8770
57	3249	185193	7.5498	3.8485	117	13689	1601613	10.8167	4.8910
58	3364	195112	7.6158	3.8709	118	13924	1643032	10.8628	4.9049
59	3481	205379	7.6811	3.8930	119	14161	1685159	10.9087	4.9187
60	3600	216000	7.7460	3.9149	120	14400	1728000	10.9545	4.9324

TABLE OF SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000—Continued.

No.	Square	Cube.	Sq. Rt.	C. Rt.	No.	Square	Cube.	Sq. Rt.	C. Rt.
121	14641	1771561	11.0000	4.9461	186	34596	6434856	13.6382	5.7083
122	14884	1815848	11.0454	4.9597	187	34969	6539203	13.6748	5.7185
123	15129	1860867	11.0905	4.9732	188	35344	6644672	13.7113	5.7287
124	15376	1906624	11.1355	4.9866	189	35721	6751269	13.7477	5.7388
125	15625	1953125	11.1803	5.0000	190	36100	6859000	13.7840	5.7489
126	15876	2000376	11.2250	5.0133	191	36481	6967871	13.8203	5.7590
127	16129	2048383	11.2694	5.0265	192	36864	7077888	13.8564	5.7690
128	16384	2097152	11.3137	5.0397	193	37249	7189057	13.8924	5.7790
129	16641	2146689	11.3578	5.0528	194	37636	7301384	13.9284	5.7890
130	16900	2197000	11.4018	5.0658	195	38025	7414875	13.9642	5.7989
131	17161	2248091	11.4455	5.0788	196	38416	7529536	14.0000	5.8088
132	17424	2299968	11.4891	5.0916	197	38809	7645373	14.0357	5.8186
133	17689	2352637	11.5326	5.1045	198	39204	7762392	14.0712	5.8285
134	17956	2406104	11.5758	5.1172	199	39601	7880599	14.1067	5.8383
135	18225	2460375	11.6190	5.1299	200	40000	8000000	14.1421	5.8480
136	18496	2515456	11.6619	5.1426	201	40401	8120601	14.1774	5.8578
137	18769	2571353	11.7047	5.1551	202	40804	8242408	14.2127	5.8675
138	19044	2628072	11.7473	5.1676	203	41209	8365427	14.2478	5.8771
139	19321	2685619	11.7898	5.1801	204	41616	8489664	14.2829	5.8868
140	19600	2744000	11.8322	5.1925	205	42025	8615125	14.3178	5.8964
141	19881	2803221	11.8743	5.2048	206	42436	8741816	14.3527	5.9059
142	20164	2863288	11.9164	5.2171	207	42849	8869743	14.3875	5.9155
143	20449	2924207	11.9583	5.2293	208	43264	8998912	14.4222	5.9250
144	20736	2985984	12.0000	5.2415	209	43681	9129329	14.4568	5.9345
145	21025	3048625	12.0416	5.2536	210	44100	9261000	14.4914	5.9439
146	21316	3112136	12.0830	5.2656	211	44521	9393931	14.5258	5.9533
147	21609	3176523	12.1244	5.2776	212	44944	9528128	14.5602	5.9627
148	21904	3241792	12.1655	5.2896	213	45369	9663597	14.5945	5.9721
149	22201	3307949	12.2066	5.3015	214	45796	9800344	14.6287	5.9814
150	22500	3375000	12.2474	5.3133	215	46225	9938375	14.6629	5.9907
151	22801	3442951	12.2882	5.3251	216	46656	10077696	14.6969	6.0000
152	23104	3511808	12.3288	5.3368	217	47089	10218313	14.7309	6.0092
153	23409	3581577	12.3693	5.3485	218	47524	10360232	14.7648	6.0185
154	23716	3652264	12.4097	5.3601	219	47961	10503459	14.7986	6.0277
155	24025	3723875	12.4499	5.3717	220	48400	10648000	14.8324	6.0368
156	24336	3796416	12.4900	5.3832	221	48841	10793861	14.8661	6.0459
157	24649	3869893	12.5300	5.3947	222	49284	10941048	14.8997	6.0550
158	24964	3944312	12.5698	5.4061	223	49729	11089567	14.9332	6.0641
159	25281	4019679	12.6095	5.4175	224	50176	11239424	14.9666	6.0732
160	25600	4096000	12.6491	5.4288	225	50625	11390625	15.0000	6.0822
161	25921	4173281	12.6886	5.4401	226	51076	11543176	15.0333	6.0912
162	26244	4251528	12.7279	5.4514	227	51529	11697083	15.0665	6.1002
163	26569	4330747	12.7671	5.4626	228	51984	11852352	15.0997	6.1091
164	26896	4410944	12.8062	5.4737	229	52441	12008989	15.1327	6.1180
165	27225	4492125	12.8452	5.4848	230	52900	12167000	15.1658	6.1269
166	27556	4574296	12.8841	5.4959	231	53361	12326391	15.1987	6.1358
167	27889	4657463	12.9228	5.5069	232	53824	12487168	15.2312	6.1446
168	28224	4741632	12.9615	5.5178	233	54289	12649337	15.2643	6.1534
169	28561	4826809	13.0000	5.5288	234	54756	12812904	15.2971	6.1622
170	28900	4913000	13.0384	5.5397	235	55225	12977875	15.3297	6.1710
171	29241	5000211	13.0767	5.5505	236	55696	13144256	15.3623	6.1797
172	29584	5088448	13.1149	5.5613	237	56169	13312053	15.3948	6.1885
173	29929	5177717	13.1529	5.5721	238	56644	13481272	15.4272	6.1972
174	30276	5268024	13.1909	5.5828	239	57121	13651919	15.4596	6.2058
175	30625	5359375	13.2288	5.5934	240	57600	13824000	15.4919	6.2145
176	30976	5451776	13.2665	5.6041	241	58081	13997521	15.5242	6.2231
177	31329	5545233	13.3041	5.6147	242	58564	14172488	15.5563	6.2317
178	31684	5639752	13.3417	5.6252	243	59049	14348907	15.5885	6.2403
179	32041	5735339	13.3791	5.6357	244	59536	14526784	15.6205	6.2488
180	32400	5832000	13.4164	5.6462	245	60025	14706125	15.6525	6.2573
181	32761	5929741	13.4536	5.6567	246	60516	14886936	15.6844	6.2658
182	33124	6028568	13.4907	5.6671	247	61009	15069223	15.7162	6.2743
183	33489	6128487	13.5277	5.6774	248	61504	15252992	15.7480	6.2828
184	33856	6229504	13.5647	5.6877	249	62001	15438249	15.7797	6.2912
185	34225	6331625	13.6015	5.6980	250	62500	15625000	15.8114	6.2969

TABLE OF SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000—Continued.

No.	Square	Cube.	Sq. Rt.	C. Rt.	No.	Square.	Cube.	Sq. Rt.	C. Rt.
251	63001	15813251	15.8430	6.3080	316	99856	31554496	17.7764	6.8113
252	63504	16003008	15.8745	6.3164	317	100489	31855013	17.8045	6.8185
253	64009	16194277	15.9060	6.3247	318	101124	32157432	17.8326	6.8256
254	64516	16387064	15.9374	6.3330	319	101761	32461759	17.8606	6.8328
255	65025	16581375	15.9687	6.3413	320	102400	32768000	17.8885	6.8399
256	65536	16777216	16.0000	6.3496	321	103041	33076161	17.9165	6.8470
257	66049	16974593	16.0312	6.3579	322	103684	33386248	17.9444	6.8541
258	66564	17173512	16.0624	6.3661	323	104329	33698267	17.9722	6.8612
259	67081	17373979	16.0935	6.3743	324	104976	34012224	18.0000	6.8683
260	67600	17576000	16.1245	6.3825	325	105625	34328125	18.0278	6.8753
261	68121	17779581	16.1555	6.3907	326	106276	34645976	18.0555	6.8824
262	68644	17984728	16.1864	6.3988	327	106929	34965783	18.0831	6.8894
263	69169	18191447	16.2173	6.4070	328	107584	35287552	18.1108	6.8964
264	69696	18399744	16.2481	6.4151	329	108241	35611289	18.1384	6.9034
265	70225	18609625	16.2788	6.4232	330	108900	35937000	18.1659	6.9104
266	70756	18821096	16.3095	6.4312	331	109561	36264691	18.1934	6.9174
267	71289	19034163	16.3401	6.4393	332	110224	36594368	18.2209	6.9244
268	71824	19248832	16.3707	6.4473	333	110889	36926037	18.2483	6.9313
269	72361	19465109	16.4012	6.4553	334	111556	37259704	18.2757	6.9382
270	72900	19683000	16.4317	6.4633	335	112225	37595375	18.3030	6.9451
271	73441	19902511	16.4621	6.4713	336	112896	37933056	18.3303	6.9521
272	73984	20123648	16.4924	6.4792	337	113569	38272753	18.3576	6.9589
273	74529	20346417	16.5227	6.4872	338	114244	38614472	18.3848	6.9658
274	75076	20570824	16.5529	6.4951	339	114921	38958219	18.4120	6.9727
275	75625	20796875	16.5831	6.5030	340	115600	39304000	18.4391	6.9795
276	76176	21024576	16.6132	6.5108	341	116281	39651821	18.4662	6.9864
277	76729	21253933	16.6433	6.5187	342	116964	40001688	18.4932	6.9932
278	77284	21484952	16.6733	6.5265	343	117649	40353607	18.5203	7.0000
279	77841	21717639	16.7033	6.5343	344	118336	40707584	18.5472	7.0068
280	78400	21952000	16.7332	6.5421	345	119025	41063625	18.5742	7.0136
281	78961	22188041	16.7631	6.5499	346	119716	41421736	18.6011	7.0203
282	79524	22425768	16.7929	6.5577	347	120409	41781923	18.6279	7.0271
283	80089	22665187	16.8226	6.5654	348	121104	42144192	18.6548	7.0338
284	80656	22906304	16.8523	6.5731	349	121801	42508549	18.6815	7.0406
285	81225	23149125	16.8819	6.5808	350	122500	42875000	18.7083	7.0473
286	81796	23393656	16.9115	6.5885	351	123201	43243551	18.7350	7.0540
287	82369	23639903	16.9411	6.5962	352	123904	43614208	18.7617	7.0607
288	82944	23887872	16.9706	6.6039	353	124609	43986977	18.7883	7.0674
289	83521	24137569	17.0000	6.6115	354	125316	44361864	18.8149	7.0740
290	84100	24389000	17.0294	6.6191	355	126025	44738875	18.8414	7.0807
291	84681	24642171	17.0587	6.6267	356	126736	45118016	18.8680	7.0873
292	85264	24897088	17.0880	6.6343	357	127449	45499293	18.8944	7.0940
293	85849	25153757	17.1172	6.6419	358	128164	45882712	18.9209	7.1006
294	86436	25412184	17.1464	6.6494	359	128881	46268279	18.9473	7.1072
295	87025	25672375	17.1756	6.6569	360	129600	46656000	18.9737	7.1138
296	87616	25934336	17.2047	6.6644	361	130321	47045881	19.0000	7.1204
297	88209	26198073	17.2337	6.6719	362	131044	47437928	19.0263	7.1269
298	88804	26463592	17.2627	6.6794	363	131769	47832147	19.0526	7.1335
299	89401	26730899	17.2916	6.6869	364	132496	48228544	19.0788	7.1400
300	90000	27000000	17.3205	6.6943	365	133225	48627125	19.1050	7.1466
301	90601	27270901	17.3494	6.7018	366	133956	49027896	19.1311	7.1531
302	91204	27543608	17.3781	6.7092	367	134689	49430863	19.1572	7.1596
303	91809	27818127	17.4069	6.7166	368	135424	49836032	19.1833	7.1661
304	92416	28094464	17.4356	6.7240	369	136161	50243409	19.2094	7.1726
305	93025	28372625	17.4642	6.7313	370	136900	50653000	19.2354	7.1791
306	93636	28652616	17.4929	6.7387	371	137641	51064811	19.2614	7.1855
307	94249	28934443	17.5214	6.7460	372	138384	51478848	19.2873	7.1920
308	94864	29218112	17.5499	6.7533	373	139129	51895117	19.3132	7.1984
309	95481	29503629	17.5784	6.7606	374	139876	52313624	19.3391	7.2048
310	96100	29791000	17.6068	6.7679	375	140625	52734375	19.3649	7.2112
311	96721	30080231	17.6352	6.7752	376	141376	53157376	19.3907	7.2177
312	97344	30371328	17.6635	6.7824	377	142129	53582633	19.4165	7.2240
313	97969	30664297	17.6918	6.7897	378	142884	54010152	19.4422	7.2304
314	98596	30959144	17.7200	6.7969	379	143641	54439939	19.4679	7.2368
315	99225	31255875	17.7482	6.8041	380	144400	54872000	19.4936	7.2432

TABLE OF SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS, OF NUMBERS FROM 1 TO 1000—Continued.

No.	Square	Cube.	Sq. Rt.	C. Rt.	No.	Square.	Cube.	Sq. Rt.	C. Rt.
381	145161	55306341	19.5192	7.2495	446	198916	88716536	21.1187	7.6403
382	145924	55742968	19.5448	7.2558	447	199809	89314623	21.1424	7.6460
383	146689	56181887	19.5704	7.2622	448	200704	89915392	21.1660	7.6517
384	147456	56623104	19.5959	7.2685	449	201601	90518849	21.1896	7.6574
385	148225	57066625	19.6214	7.2748	450	202500	91125000	21.2132	7.6631
386	148996	57512456	19.6469	7.2811	451	203401	91733851	21.2368	7.6688
387	149769	57960603	19.6723	7.2874	452	204304	92345408	21.2603	7.6744
388	150544	58411072	19.6977	7.2936	453	205209	92959677	21.2838	7.6801
389	151321	58863869	19.7231	7.2999	454	206116	93576664	21.3073	7.6857
390	152100	59319000	19.7484	7.3061	455	207025	94196375	21.3307	7.6914
391	152881	59776471	19.7737	7.3124	456	207936	94818816	21.3542	7.6970
392	153664	60236288	19.7990	7.3186	457	208849	95443993	21.3776	7.7026
393	154449	60698457	19.8242	7.3248	458	209764	96071912	21.4009	7.7082
394	155236	61162984	19.8494	7.3310	459	210681	96702579	21.4243	7.7138
395	156025	61629875	19.8746	7.3372	460	211600	97336000	21.4476	7.7194
396	156816	62099136	19.8997	7.3434	461	212521	97972181	21.4709	7.7250
397	157609	62570773	19.9249	7.3496	462	213444	98611128	21.4942	7.7306
398	158404	63044792	19.9499	7.3558	463	214369	99252847	21.5174	7.7362
399	159201	63521199	19.9750	7.3619	464	215296	99897344	21.5407	7.7418
400	160000	64000000	20.0000	7.3681	465	216225	100544625	21.5639	7.7473
401	160801	64481201	20.0250	7.3742	466	217156	101194696	21.5870	7.7529
402	161604	64964808	20.0499	7.3803	467	218089	101847563	21.6102	7.7584
403	162409	65450827	20.0749	7.3864	468	219024	102503232	21.6333	7.7639
404	163216	65939264	20.0998	7.3925	469	219961	103161709	21.6564	7.7695
405	164025	66430125	20.1246	7.3986	470	220900	103823000	21.6795	7 7750
406	164836	66923416	20.1494	7.4047	471	221841	104487111	21.7025	7.7805
407	165649	67419143	20.1742	7.4108	472	222784	105154048	21.7256	7.7860
408	166464	67917312	20.1990	7.4169	473	223729	105823817	21.7486	7.7915
409	167281	68417929	20.2237	7.4229	474	224676	106496424	21.7715	7.7970
410	168100	68921000	20.2485	7.4290	475	225625	107171875	21 7945	7.8025
411	168921	69426531	20.2731	7.4350	476	226576	107850176	21.8174	7.8079
412	169744	69934528	20 2978	7 4410	477	227529	108531333	21.8403	7.8134
413	170569	70444997	20.3224	7.4470	478	228484	109215352	21.8632	7.8188
414	171396	70957944	20.3470	7.4530	479	229441	109902239	21.8861	7.8243
415	172225	71473375	20.3715	7.4590	480	230400	110592000	21.9089	7.8297
416	173056	71991296	20.3961	7.4650	481	231361	111284641	21.9317	7.8352
417	173889	72511713	20.4206	7.4710	482	232324	111980168	21.9545	7.8406
418	174724	73034632	20.4450	7.4770	483	233289	112678587	21.9773	7.8460
419	175561	73560059	20.4695	7.4829	484	234256	113379904	22.0000	7.8514
420	176400	74088000	20.4939	7.4889	485	235225	114084125	22.0227	7.8568
421	177241	74618461	20.5183	7.4948	486	236196	114791256	22.0454	7 8622
422	178084	75151448	20.5426	7.5007	487	237169	115501303	22.0681	7.8676
423	178929	75686967	20.5670	7 5067	488	238144	116214272	22.0907	7.8730
424	179776	76225024	20.5913	7.5126	489	239121	116930169	22.1133	7.8784
425	180625	76765625	20.6155	7.5185	490	240100	117649000	22.1359	7.8837
426	181476	77308776	20.6398	7.5244	491	241081	118370771	22.1585	7.8891
427	182329	77854483	20.6640	7.5302	492	242064	119095488	22.1811	7 8944
428	183184	78402752	20.6882	7.5361	493	243049	119823157	22.2036	7.8998
429	184041	78953589	20.7123	7.5420	494	244036	120553784	22.2261	7.9051
430	184900	79507000	20.7364	7 5478	495	245025	121287375	22.2486	7.9105
431	185761	80062991	20.7605	7.5537	496	246016	122023936	22.2711	7 9158
432	186624	80621568	20.7846	7.5595	497	247009	122763473	22.2935	7.9211
433	187489	81182737	20.8087	7.5654	498	248004	123505992	22.3159	7.9264
434	188356	81746504	20.8327	7.5712	499	249001	124251499	22.3383	7.9317
435	189225	82312875	20.8567	7.5770	500	250000	125000000	22.3607	7 9370
436	190096	82881856	20.8806	7 5828	501	251001	125751501	22 3830	7.9423
437	190969	83453453	20.9045	7.5886	502	252004	126506008	22.4054	7.9476
438	191844	84027672	20.9284	7.5944	503	253009	127263527	22.4277	7.9528
439	192721	84604519	20.9523	7.6001	504	254016	128024064	22.4499	7.9581
440	193600	85184000	20.9762	7.6059	505	255025	128787625	22.4722	7.9634
441	194481	85766121	21.0000	7.6117	506	256036	129554216	22.4944	7.9686
442	195364	86350888	21.0238	7.6174	507	257049	130323843	22 5117	7.9739
443	196249	86938307	21.0476	7.6232	508	258064	131096512	22.5389	7.9791
444	197136	87528384	21.0713	7.6289	509	259081	131872229	22.5610	7.9843
445	198025	88121125	21.0950	7.6346	510	260100	132651000	22.5832	7.9896

TABLE OF SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS, OF NUMBERS FROM 1 TO 1000—Continued.

No.	Square	Cube.	Sq. Rt.	C. Rt.	No.	Square	Cube.	Sq. Rt.	C. Rt.
511	261121	133432831	22.6053	7.9948	576	331776	191102976	24.0000	8.3203
512	262144	134217728	22.6274	8.0000	577	332929	192100033	24.0208	8.3251
513	263169	135005697	22.6495	8.0052	578	334084	193100552	24.0416	8.3300
514	264196	135796744	22.6716	8.0104	579	335241	194104539	24.0624	8.3348
515	265225	136590875	22.6936	8.0156	580	336400	195112000	24.0832	8.3396
516	266256	137388096	22.7156	8.0208	581	337561	196122941	24.1039	8.3443
517	267289	138188413	22.7376	8.0260	582	338724	197137368	24.1247	8.3491
518	268324	138991832	22.7596	8.0311	583	339889	198155287	24.1454	8.3539
519	269361	139798359	22.7816	8.0363	584	341056	199176704	24.1661	8.3587
520	270400	140608000	22.8035	8.0415	585	342225	200201625	24.1868	8.3634
521	271441	141420761	22.8254	8.0466	586	343396	201230056	24.2074	8.3682
522	272484	142236648	22.8473	8.0517	587	344569	202262003	24.2281	8.3730
523	273529	143055667	22.8692	8.0569	588	345744	203297472	24.2487	8.3777
524	274576	143877824	22.8910	8.0620	589	346921	204336469	24.2693	8.3825
525	275625	144703125	22.9129	8.0671	590	348100	205379000	24.2899	8.3872
526	276676	145531576	22.9347	8.0723	591	349281	206425071	24.3105	8.3919
527	277729	146363183	22.9565	8.0774	592	350464	207474688	24.3311	8.3967
528	278784	147197952	22.9783	8.0825	593	351649	208527857	24.3516	8.4014
529	279841	148035889	23.0000	8.0876	594	352836	209584584	24.3721	8.4061
530	280900	148877000	23.0217	8.0927	595	354025	210644875	24.3926	8.4108
531	281961	149721291	23.0434	8.0978	596	355216	211708736	24.4131	8.4155
532	283024	150568768	23.0651	8.1028	597	356409	212776173	24.4336	8.4202
533	284089	151419437	23.0868	8.1079	598	357604	213847192	24.4540	8.4249
534	285156	152273304	23.1084	8.1130	599	358801	214921799	24.4745	8.4296
535	286225	153130375	23.1301	8.1180	600	360000	216000000	24.4949	8.4343
536	287296	153990656	23.1517	8.1231	601	361201	217081801	24.5153	8.4390
537	288369	154854153	23.1733	8.1281	602	362404	218167208	24.5357	8.4437
538	289444	155720872	23.1948	8.1332	603	363609	219256227	24.5561	8.4484
539	290521	156590819	23.2164	8.1382	604	364816	220348864	24.5764	8.4530
540	291600	157464000	23.2379	8.1433	605	366025	221445125	24.5967	8.4577
541	292681	158340421	23.2594	8.1483	606	367236	222545016	24.6171	8.4623
542	293764	159220088	23.2809	8.1533	607	368449	223648543	24.6374	8.4670
543	294849	160103007	23.3024	8.1583	608	369664	224755712	24.6577	8.4716
544	295936	160989184	23.3238	8.1633	609	370881	225866529	24.6779	8.4763
545	297025	161878625	23.3452	8.1683	610	372100	226981000	24.6982	8.4809
546	298116	162771336	23.3666	8.1733	611	373321	228099131	24.7184	8.4856
547	299209	163667323	23.3880	8.1783	612	374544	229220928	24.7386	8.4902
548	300304	164566592	23.4094	8.1833	613	375769	230346397	24.7588	8.4948
549	301401	165469149	23.4307	8.1882	614	376996	231475544	24.7790	8.4994
550	302500	166375000	23.4521	8.1932	615	378225	232608375	24.7992	8.5040
551	303601	167284151	23.4734	8.1982	616	379456	233744896	24.8193	8.5086
552	304704	168196608	23.4947	8.2031	617	380689	234885113	24.8395	8.5132
553	305809	169112377	23.5160	8.2081	618	381924	236029032	24.8596	8.5178
554	306916	170031464	23.5372	8.2130	619	383161	237176659	24.8797	8.5224
555	308025	170953875	23.5584	8.2180	620	384400	238328000	24.8998	8.5270
556	309136	171879616	23.5797	8.2229	621	385641	239483061	24.9199	8.5316
557	310249	172808693	23.6008	8.2278	622	386884	240641848	24.9399	8.5362
558	311364	173741112	23.6220	8.2327	623	388129	241804367	24.9600	8.5408
559	312481	174676879	23.6432	8.2377	624	389376	242970624	24.9800	8.5453
560	313600	175616000	23.6643	8.2426	625	390625	244140625	25.0000	8.5499
561	314721	176558481	23.6854	8.2475	626	391876	245314376	25.0200	8.5544
562	315844	177504328	23.7065	8.2524	627	393129	246491883	25.0400	8.5590
563	316969	178453547	23.7276	8.2573	628	394384	247673152	25.0599	8.5635
564	318096	179406144	23.7487	8.2621	629	395641	248858189	25.0799	8.5681
565	319225	180362125	23.7697	8.2670	630	396900	250047000	25.0998	8.5726
566	320356	181321496	23.7908	8.2719	631	398161	251239591	25.1197	8.5772
567	321489	182284263	23.8118	8.2768	632	399424	252435968	25.1396	8.5817
568	322624	183250432	23.8328	8.2816	633	400689	253636137	25.1595	8.5862
569	323761	184220009	23.8537	8.2865	634	401956	254840104	25.1794	8.5907
570	324900	185193000	23.8747	8.2913	635	403225	256047875	25.1992	8.5952
571	326041	186169411	23.8956	8.2962	636	404496	257259456	25.2190	8.5997
572	327184	187149248	23.9165	8.3010	637	405769	258474853	23.2389	8.6043
573	328329	188132517	23.9374	8.3059	638	407044	259694072	25.2587	8.6088
574	329476	189119224	23.9583	8.3107	639	408321	260917119	25.2784	8.6132
575	330625	190109375	23.9792	8.3155	640	409600	262144000	25.2982	8.6177

TABLE OF SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000—Continued.

No.	Square	Cube.	Sq. Rt.	C. Rt.	No.	Square	Cube.	Sq. Rt.	C. Rt.
641	410881	263374721	25.3180	8.6222	706	498436	351895816	26.5707	8.9043
642	412164	264609288	25.3377	8.6267	707	499849	353393243	26.5895	8.9085
643	413449	265847707	25.3574	8.6312	708	501264	354894912	26.6083	8.9127
644	414736	267089984	25.3772	8.6357	709	502681	356400829	26.6271	8.9169
645	416025	268336125	25.3969	8.6401	710	504100	357911000	26.6458	8.9211
646	417316	269586136	25.4165	8.6446	711	505521	359425431	26.6646	8.9253
647	418609	270840023	25.4362	8.6490	712	506944	360944128	26.6833	8.9295
648	419904	272097792	25.4558	8.6535	713	508369	362467097	26.7021	8.9337
649	421201	273359449	25.4755	8.6579	714	509796	363994344	26.7208	8.9378
650	422500	274625000	25.4951	8.6624	715	511225	365525875	26.7395	8.9420
651	423801	275894451	25.5147	8.6668	716	512656	367061696	26.7582	8.9462
652	425104	277167808	25.5343	8.6713	717	514089	368601813	26.7769	8.9503
653	426409	278445077	25.5539	8.6757	718	515524	370146232	26.7955	8.9545
654	427716	279726264	25.5734	8.6801	719	516961	371694959	26.8142	8.9587
655	429025	281011375	25.5930	8.6845	720	518400	373248000	26.8328	8.9628
656	430336	282300416	25.6125	8.6890	721	519841	374805361	26.8514	8.9670
657	431649	283593393	25.6320	8.6934	722	521284	376367048	26.8701	8.9711
658	432964	284890312	25.6515	8.6978	723	522729	377933067	26.8887	8.9752
659	434281	286191179	25.6710	8.7022	724	524176	379503424	26.9072	8.9794
660	435600	287496000	25.6905	8.7066	725	525625	381078125	26.9258	8.9835
661	436921	288804781	25.7099	8.7110	726	527076	382657176	26.9444	8.9876
662	438244	290117528	25.7294	8.7154	727	528529	384240583	26.9629	8.9918
663	439569	291434247	25.7488	8.7198	728	529984	385828352	26.9815	8.9959
664	440896	292754944	25.7682	8.7241	729	531441	387420489	27.0000	9.0000
665	442225	294079625	25.7876	8.7285	730	532900	389017000	27.0185	9.0041
666	443556	295408296	25.8070	8.7329	731	534361	390617891	27.0370	9.0082
667	444889	296740963	25.8263	8.7373	732	535824	392223168	27.0555	9.0123
668	446224	298077632	25.8457	8.7416	733	537289	393832837	27.0740	9.0164
669	447561	299418309	25.8650	8.7460	734	538756	395446904	27.0924	9.0205
670	448900	300763000	25.8844	8.7503	735	540225	397065375	27.1109	9.0246
671	450241	302111711	25.9037	8.7547	736	541696	398688256	27.1293	9.0287
672	451584	303464448	25.9230	8.7590	737	543169	400315553	27.1477	9.0328
673	452929	304821217	25.9422	8.7634	738	544644	401947272	27.1662	9.0369
674	454276	306182024	25.9615	8.7677	739	546121	403583419	27.1846	9.0410
675	455625	307546875	25.9808	8.7721	740	547600	405224000	27.2029	9.0450
676	456976	308915776	26.0000	8.7764	741	549081	406869021	27.2213	9.0491
677	458329	310288733	26.0192	8.7807	742	550564	408518488	27.2397	9.0532
678	459684	311665752	26.0384	8.7850	743	552049	410172407	27.2580	9.0572
679	461041	313046839	26.0576	8.7893	744	553536	411830784	27.2764	9.0613
680	462400	314432000	26.0768	8.7937	745	555025	413493625	27.2947	9.0654
681	463761	315821241	26.0960	8.7980	746	556516	415160936	27.3130	9.0694
682	465124	317214568	26.1151	8.8023	747	558009	416832723	27.3313	9.0735
683	466489	318611987	26.1343	8.8066	748	559504	418508992	27.3496	9.0775
684	467856	320013504	26.1534	8.8109	749	561001	420189749	27.3679	9.0816
685	469225	321419125	26.1725	8.8152	750	562500	421875000	27.3861	9.0856
686	470596	322828856	26.1916	8.8194	751	564001	423564751	27.4044	9.0896
687	471969	324242703	26.2107	8.8237	752	565504	425259008	27.4226	9.0937
688	473344	325660672	26.2298	8.8280	753	567009	426957777	27.4408	9.0977
689	474721	327082769	26.2488	8.8323	754	568516	428661064	27.4591	9.1017
690	476100	328509000	26.2679	8.8366	755	570025	430368875	27.4773	9.1057
691	477481	329939371	26.2869	8.8408	756	571536	432081216	27.4955	9.1098
692	478864	331373888	26.3059	8.8451	757	573049	433798093	27.5136	9.1138
693	480249	332812557	26.3249	8.8493	758	574564	435519512	27.5318	9.1178
694	481636	334255384	26.3439	8.8536	759	576081	437245479	27.5500	9.1218
695	483025	335702375	26.3629	8.8578	760	577600	438976000	27.5681	9.1258
696	484416	337153536	26.3818	8.8621	761	579121	440711081	27.5862	9.1298
697	485809	338608873	26.4008	8.8663	762	580644	442450728	27.6043	9.1338
698	487204	340068392	26.4197	8.8706	763	582169	444194947	27.6225	9.1378
699	488601	341532099	26.4386	8.8748	764	583696	445943744	27.6405	9.1418
700	490000	343000000	26.4575	8.8790	765	585225	447697125	27.6586	9.1458
701	491401	344472101	26.4764	8.8833	766	586756	449455096	27.6767	9.1498
702	492804	345948408	26.4953	8.8875	767	588289	451217663	27.6948	9.1537
703	494209	347428927	26.5141	8.8917	768	589824	452984832	27.7128	9.1577
704	495616	348913664	26.5330	8.8959	769	591361	454756609	27.7308	9.1617
705	497025	350402625	26.5518	8.9001	770	592900	456533000	27.7489	9.1657

TABLE OF SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000—Continued.

No.	Square	Cube.	Sq. Rt.	C. Rt.	No.	Square	Cube.	Sq. Rt.	C. Rt.
771	594441	458314011	27.7669	9.1696	836	698896	584277056	28.9137	9.4204
772	595984	460099648	27.7849	9.1736	837	700569	586376253	28.9310	9.4241
773	597529	461889917	27.8029	9.1775	838	702244	588480472	28.9482	9.4279
774	599076	463684824	27.8209	9.1815	839	703921	590589719	28.9655	9.4316
775	600625	465484375	27.8388	9.1855	840	705600	592704000	28.9828	9.4354
776	602176	467288576	27.8568	9.1894	841	707281	594823321	29.0000	9.4391
777	603729	469097433	27.8747	9.1933	842	708964	596947688	29.0172	9.4429
778	605284	470910952	27.8927	9.1973	843	710649	599077107	29.0345	9.4466
779	606841	472729139	27.9106	9.2012	844	712336	601211584	29.0517	9.4503
780	608400	474552000	27.9285	9.2052	845	714025	603351125	29.0689	9.4541
781	609961	476379541	27.9464	9.2091	846	715716	605495736	29.0861	9.4578
782	611524	478211768	27.9643	9.2130	847	717409	607645423	29.1033	9.4615
783	613089	480048687	27.9821	9.2170	848	719104	609800192	29.1204	9.4652
784	614656	481890304	28.0000	9.2209	849	720801	611960049	29.1376	9.4690
785	616225	483736625	28.0179	9.2248	850	722500	614125000	29.1548	9.4727
786	617796	485587656	28.0357	9.2287	851	724201	616295051	29.1719	9.4764
787	619369	487443403	28.0535	9.2326	852	725904	618470208	29.1890	9.4801
788	620944	489303872	28.0713	9.2365	853	727609	620650477	29.2062	9.4838
789	622521	491169069	28.0891	9.2404	854	729316	622835864	29.2233	9.4875
790	624100	493039000	28.1069	9.2443	855	731025	625026375	29.2404	9.4912
791	625681	494913671	28.1247	9.2482	856	732736	627222016	29.2575	9.4949
792	627264	496793088	28.1425	9.2521	857	734449	629422793	29.2746	9.4986
793	628849	498677257	28.1603	9.2560	858	736164	631628712	29.2916	9.5023
794	630436	500566184	28.1780	9.2599	859	737881	633839779	29.3087	9.5060
795	632025	502459875	28.1957	9.2638	860	739600	636056000	29.3258	9.5097
796	633616	504358336	28.2135	9.2677	861	741321	638277381	29.3428	9.5134
797	635209	506261573	28.2312	9.2716	862	743044	640503928	29.3598	9.5171
798	636804	508169592	28.2489	9.2754	863	744769	642735647	29.3769	9.5207
799	638401	510082399	28.2666	9.2793	864	746496	644972544	29.3939	9.5244
800	640000	512000000	28.2843	9.2832	865	748225	647214625	29.4109	9.5281
801	641601	513922401	28.3019	9.2870	866	749956	649461896	29.4279	9.5317
802	643204	515849608	28.3196	9.2909	867	751689	651714363	29.4449	9.5354
803	644809	517781627	28.3373	9.2948	868	753424	653972032	29.4618	9.5391
804	646416	519718464	28.3549	9.2986	869	755161	656234909	29.4788	9.5427
805	648025	521660125	28.3725	9.3025	870	756900	658503000	29.4958	9.5464
806	649636	523606616	28.3901	9.3063	871	758641	660776311	29.5127	9.5501
807	651249	525557943	28.4077	9.3102	872	760384	663054848	29.5296	9.5537
808	652864	527514112	28.4253	9.3140	873	762129	665338617	29.5466	9.5574
809	654481	529475129	28.4429	9.3179	874	763876	667627624	29.5635	9.5610
810	656100	531441000	28.4605	9.3217	875	765625	669921875	29.5804	9.5647
811	657721	533411731	28.4781	9.3255	876	767376	672221376	29.5973	9.5683
812	659344	535387328	28.4956	9.3294	877	769129	674526133	29.6142	9.5719
813	660969	537367797	28.5132	9.3332	878	770884	676836152	29.6311	9.5756
814	662596	539353144	28.5307	9.3370	879	772641	679151439	29.6479	9.5792
815	664225	541343375	28.5482	9.3408	880	774400	681472000	29.6648	9.5828
816	665856	543338496	28.5657	9.3447	881	776161	683797841	29.6816	9.5865
817	667489	545338513	28.5832	9.3485	882	777924	686128968	29.6985	9.5901
818	669124	547343432	28.6007	9.3523	883	779689	688465387	29.7153	9.5937
819	670761	549353259	28.6182	9.3561	884	781456	690807104	29.7321	9.5973
820	672400	551368000	28.6356	9.3599	885	783225	693154125	29.7489	9.6010
821	674041	553387661	28.6531	9.3637	886	784996	695506456	29.7658	9.6046
822	675684	555412248	28.6705	9.3675	887	786769	697864103	29.7825	9.6082
823	677329	557441767	28.6880	9.3713	888	788544	700227072	29.7993	9.6118
824	678976	559476224	28.7054	9.3751	889	790321	702595369	29.8161	9.6154
825	680625	561515625	28.7228	9.3789	890	792100	704969000	29.8329	9.6190
826	682276	563559976	28.7402	9.3827	891	793881	707347971	29.8496	9.6226
827	683929	565609283	28.7576	9.3865	892	795664	709732288	29.8664	9.6262
828	685584	567663552	28.7750	9.3902	893	797449	712121957	29.8831	9.6298
829	687241	569722789	28.7924	9.3940	894	799236	714516984	29.8998	9.6334
830	688900	571787000	28.8097	9.3978	895	801025	716917375	29.9166	9.6370
831	690561	573856191	28.8271	9.4016	896	802816	719323136	29.9333	9.6406
832	692224	575930368	28.8444	9.4053	897	804609	721734273	29.9500	9.6442
833	693889	578009537	28.8617	9.4091	898	806404	724150792	29.9666	9.6477
834	695556	580093704	28.8791	9.4129	899	808201	726572699	29.9833	9.6513
835	697225	582182875	28.8964	9.4166	900	810000	729000000	30.0000	9.6549

TABLE OF SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS OF NUMBERS FROM 1 TO 1000—Concluded.

No.	Square	Cube.	Sq. Rt.	C. Rt.	No.	Square	Cube.	Sq. Rt.	C. Rt.
901	811801	731432701	30.0167	9.6585	951	904401	860085351	30.8383	9.8339
902	813604	733870808	30.0333	9.6620	952	906304	862801408	30.8545	9.8374
903	815409	736314327	30.0500	9.6656	953	908209	865523177	30.8707	9.8408
904	817216	738763264	30.0666	9.6692	954	910116	868250664	30.8869	9.8443
905	819025	741217625	30.0832	9.6727	955	912025	870983875	30.9031	9.8477
906	820836	743677416	30.0998	9.6763	956	913936	873722816	30.9192	9.8511
907	822649	746142643	30.1164	9.6799	957	915849	876467493	30.9354	9.8546
908	824464	748613312	30.1330	9.6834	958	917764	879217912	30.9516	9.8580
909	826281	751089429	30.1496	9.6870	959	919681	881974079	30.9677	9.8613
910	828100	753571000	30.1662	9.6905	960	921600	884736000	30.9839	9.8648
911	829921	756058031	30.1828	9.6941	961	923521	887503681	31.0000	9.8683
912	831744	758550528	30.1993	9.6976	962	925444	890277128	31.0161	9.8717
913	833569	761048497	30.2159	9.7012	963	927369	893056347	31.0322	9.8751
914	835396	763551944	30.2324	9.7047	964	929296	895841344	31.0483	9.8785
915	837225	766060875	30.2490	9.7082	965	931225	898632125	31.0644	9.8819
916	839056	768575296	30.2655	9.7118	966	933156	901428696	31.0805	9.8854
917	840889	771095213	30.2820	9.7153	967	935089	904231063	31.0966	9.8888
918	842724	773620632	30.2985	9.7188	968	937024	907039232	31.1127	9.8922
919	844561	776151559	30.3150	9.7224	969	938961	909853209	31.1288	9.8956
920	846400	778688000	30.3315	9.7259	970	940900	912673000	31.1448	9.8990
921	848241	781229961	30.3480	9.7294	971	942841	915498611	31.1609	9.9024
922	850084	783777448	30.3645	9.7329	972	944784	918330048	31.1769	9.9058
923	851929	786330467	30.3809	9.7364	973	946729	921167317	31.1929	9.9092
924	853776	788889024	30.3974	9.7400	974	948676	924010424	31.2090	9.9126
925	855625	791453125	30.4138	9.7435	975	950625	926859375	31.2250	9.9160
926	857476	794022776	30.4302	9.7470	976	952576	929714176	31.2410	9.9194
927	859329	796597983	30.4467	9.7505	977	954529	932574833	31.2570	9.9227
928	861184	799178752	30.4631	9.7540	978	956484	935441352	31.2730	9.9261
929	863041	801765089	30.4795	9.7575	979	958441	938313739	31.2890	9.9295
930	864900	804357000	30.4959	9.7610	980	960400	941192000	31.3050	9.9329
931	866761	806954491	30.5123	9.7645	981	962361	944076141	31.3209	9.9363
932	868624	809557568	30.5287	9.7680	982	964324	946966168	31.3369	9.9396
933	870489	812166237	30.5450	9.7715	983	966289	949862087	31.3528	9.9430
934	872356	814780504	30.5614	9.7750	984	968256	952763904	31.3688	9.9464
935	874225	817400375	30.5778	9.7785	985	970225	955671625	31.3847	9.9497
936	876096	820025856	30.5941	9.7829	986	972196	958585256	31.4006	9.9531
937	877969	822656953	30.6105	9.7854	987	974169	961504803	31.4166	9.9565
938	879844	825293672	30.6268	9.7889	988	976144	964430272	31.4325	9.9598
939	881721	827936019	30.6431	9.7924	989	978121	967361669	31.4484	9.9632
940	883600	830584000	30.6594	9.7959	990	980100	970299000	31.4643	9.9666
941	885481	833237621	30.6757	9.7993	991	982081	973242271	31.4802	9.9699
942	887364	835896888	30.6920	9.8028	992	984064	976191488	31.4960	9.9733
943	889249	838561807	30.7083	9.8063	993	986049	979146657	31.5119	9.9766
944	891136	841232384	30.7246	9.8097	994	988036	982107784	31.5278	9.9800
945	893025	843908625	30.7409	9.8132	995	990025	985074875	31.5436	9.9833
946	894916	846590536	30.7571	9.8167	996	992016	988047936	31.5595	9.9866
947	896809	849278123	30.7734	9.8201	997	994009	991026973	31.5753	9.9900
948	898704	851971392	30.7896	9.8236	998	996004	994011992	31.5911	9.9933
949	900601	854670349	30.8058	9.8270	999	998001	997002999	31.6070	9.9967
950	902500	857375000	30.8221	9.8305	1000	1000000	1000000000	31.6228	10.0000

TABLE OF NATURAL SINES AND COSINES.

Prop. parts.		0°		1°		2°		3°		4°			Prop. parts.
29	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.	N. sine.	N. cos.	N. sine	N. cos.		2
0	0	00000	1.	01745	99985	0349	99939	05234	99863	06976	99756	60	2
0	1	00029	1.	01774	99984	03519	99938	05263	99861	07005	99754	59	2
1	2	00058	1.	01803	99984	03548	99937	05292	9986	07034	99752	58	2
1	3	00087	1.	01832	99983	03577	99936	05321	99858	07063	9975	57	2
2	4	00116	1.	01862	99983	03606	99935	0535	99857	07092	99748	56	2
2	5	00145	1.	01891	99982	03635	99934	05379	99855	07121	99746	55	2
3	6	00175	1.	0192	99982	03664	99933	05408	99854	0715	99744	54	2
3	7	00204	1.	01949	99981	03693	99932	05437	99852	07179	99742	53	2
4	8	00233	1.	01978	9998	03723	99931	05466	99851	07208	9974	52	2
4	9	00262	1.	02007	9998	03752	9993	05495	99849	07237	99738	51	2
5	10	00291	1.	02036	99979	03781	99929	05524	99847	07266	99736	50	2
5	11	0032	.99999	02065	99979	0381	99927	05553	99846	07295	99734	49	2
6	12	00349	99999	02094	99978	03839	99926	05582	99844	07324	99731	48	2
6	13	00378	99999	02123	99977	03868	99925	05611	99842	07353	99729	47	2
7	14	00407	99999	02152	99977	03897	99924	0564	99841	07382	99727	46	2
7	15	00436	99999	02181	99976	03926	99923	05669	99839	07411	99725	45	2
8	16	00465	99999	02211	99976	03955	99922	05698	99838	0744	99723	44	1
8	17	00495	99999	0224	99975	03984	99921	05727	99836	07469	99721	43	1
9	18	00524	99999	02269	99974	04013	99919	05756	99834	07498	99719	42	1
9	19	00553	99998	02298	99974	04042	99918	05785	99833	07527	99716	41	1
10	20	00582	99998	02327	99973	04071	99917	05814	99931	07556	99214	40	1
10	21	00611	99998	02356	99972	041	99916	05844	99829	07585	99712	39	1
11	22	0064	99998	02385	99972	04129	99915	05873	99827	07614	9971	38	1
11	23	00669	99998	02414	99971	04159	99913	05902	99826	07643	99708	37	1
12	24	00698	99998	02443	9997	04188	99912	05931	99824	07672	99705	36	1
12	25	00727	99997	02472	99969	04217	99911	0596	99822	07701	99703	35	1
13	26	00756	99997	02501	99969	04246	9991	05989	99821	0773	99701	34	1
13	27	00785	99997	0253	99968	04275	99909	06018	99819	07759	99699	33	1
14	28	00814	99997	0256	99967	04304	99907	06047	99817	07788	99696	32	1
14	29	00844	99996	02589	99966	04333	99906	06076	99815	07817	99694	31	1
15	30	00873	99996	02618	99966	04362	99905	06105	99813	07846	99692	30	1
15	31	00902	99996	02647	99965	04391	99904	06134	99812	07875	99689	29	1
15	32	00931	99996	02676	99964	0442	99902	06163	9981	07904	99687	28	1
16	33	0096	99995	02705	99963	04449	99901	06192	99808	07933	99685	27	1
16	34	00989	99995	02734	99963	04478	999	06221	99806	07962	99683	26	1
17	35	01018	99995	02763	99962	04507	99898	0625	99804	07991	9968	25	1
17	36	01047	99995	02792	99961	04536	99897	06279	99803	0802	99678	24	1
18	37	01076	99994	02821	9996	04565	99896	06308	99801	08049	99676	23	1
18	38	01105	99994	0285	99959	04594	99894	06337	99799	08078	99673	22	1
19	39	01134	99994	02879	99959	04623	99893	06366	99797	08107	99671	21	1
19	40	01164	99993	02908	99958	04653	99892	06395	99795	08136	99668	20	1
20	41	01193	99993	02938	99957	04682	9989	06424	99793	08165	99666	19	1
20	42	01222	99993	02967	99956	04711	99889	06453	99792	08194	99664	18	1
21	43	01251	99992	02996	99955	0474	99888	06482	9979	08223	99661	17	1
21	44	0128	99992	03025	99954	04769	99886	06511	99788	08252	99659	16	1
22	45	01309	99991	03054	99953	04798	99885	0654	99786	08281	99657	15	1
22	46	01338	99991	03083	99952	04827	99883	06569	99784	0831	99654	14	0
23	47	01367	99991	03112	99952	04856	99882	06598	99782	08339	99652	13	0
23	48	01396	9999	03141	99951	04885	99881	06627	9978	08368	99649	12	0
24	49	01425	9999	0317	9995	04914	99879	06656	99778	08397	99647	11	0
24	50	01454	99989	03199	99949	04943	99878	06685	99776	08426	99644	10	0
25	51	01483	99989	03228	99948	04972	99876	06714	99774	08455	99642	9	0
25	52	01513	99989	03257	99947	05001	99875	06743	99772	08484	99639	8	0
26	53	01542	99988	03286	99946	0503	99873	06773	9977	08513	99637	7	0
26	54	01571	99988	03316	99945	05059	99872	06802	99768	08542	99635	6	0
27	55	016	99987	03345	99944	05088	9987	06831	99766	08571	99632	5	0
27	56	01629	99987	03374	99943	05117	99869	0686	99764	086	9963	4	0
28	57	01658	99986	03403	99942	05146	99867	06889	99762	08629	99627	3	0
28	58	01687	99986	03432	99941	05175	99866	06918	9976	08658	99625	2	0
29	59	01716	99985	03461	9994	05205	99864	06947	99758	08687	99622	1	0
29	60	01745	99985	0349	99939	05234	99863	06976	99756	08716	99619	0	0
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	′	
		89°		88°		87°		86°		85°			

TABLE OF NATURAL SINES AND COSINES—Continued.

Prop. parts.		5°		6°		7°		8°		9°			Prop. parts.
29	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.	N. sine.	N. cos.	N. sine	N. cos.		4
0	0	08716	99619	10453	99452	12187	99255	13917	99027	15643	98769	60	4
0	1	08745	99617	10482	99449	12216	99251	13946	99023	15672	98764	59	4
1	2	08774	99614	10511	99446	12245	99248	13975	99019	15701	9876	58	4
1	3	08803	99612	1054	99443	12274	99244	14004	99015	1573	98755	57	4
2	4	08831	99609	10569	9944	12302	9924	14033	99011	15758	98751	56	4
2	5	0886	99607	10597	99437	12331	99237	14061	99006	15787	98746	55	4
3	6	08889	99604	10626	99434	1236	99233	1409	99002	15816	98741	54	4
3	7	08918	99602	10655	99431	12389	9923	14119	98998	15845	98737	53	4
4	8	08947	99599	10684	99428	12418	99226	14148	98994	15873	98732	52	3
4	9	08976	99596	10713	99424	12447	99222	14177	9899	15902	98728	51	3
5	10	09005	99594	10742	99421	12476	99219	14205	98986	15931	98723	50	3
5	11	09034	99591	10771	99418	12504	99215	14234	98982	15959	98718	49	3
6	12	09063	99588	108	99415	12533	99211	14263	98978	15988	98714	48	3
6	13	09092	99586	10829	99412	12562	99208	14292	98973	16017	98709	47	3
7	14	09121	99583	10858	99409	12591	99204	1432	98969	16046	98704	46	3
7	15	0915	9958	10887	99406	1262	992	14349	98965	16074	987	45	3
8	16	09179	99578	10916	99402	12649	99197	14378	98961	16103	98695	44	3
8	17	09208	99575	10945	99399	12678	99193	14407	98957	16132	9869	43	3
9	18	09237	99572	10973	99396	12706	99189	14436	98953	1616	98686	42	3
9	19	09266	9957	11002	99393	12735	99186	14464	98948	16189	98681	41	3
10	20	09295	99567	11031	9939	12764	99182	14493	98944	16218	98676	40	3
10	21	09324	99564	1106	99386	12793	99178	14522	9894	16246	98671	39	3
11	22	09353	99562	11089	99383	12822	99175	14551	98936	16275	98667	38	3
11	23	09382	99559	11118	9938	12851	99171	1458	98931	16304	98662	37	2
12	24	09411	99556	11147	99377	1288	99167	14608	98927	16333	98657	36	2
12	25	0944	99553	11176	99374	12908	99163	14637	98923	16361	98652	35	2
13	26	09469	99551	11205	9937	12937	9916	14666	98919	1639	98648	34	2
13	27	09498	99548	11234	99367	12966	99156	14695	98914	16419	98643	33	2
14	28	09527	99545	11263	99364	12995	99152	14723	9891	16447	98638	32	2
14	29	09556	99542	11291	9936	13024	99148	14752	98906	16476	98633	31	2
15	30	09585	9954	1132	99357	13053	99144	14781	98902	16505	98629	30	2
15	31	09614	99537	11349	99354	13081	99141	1481	98897	16533	98624	29	2
15	32	09642	99534	11378	99351	1311	99137	14838	98893	16562	98619	28	2
16	33	09671	99531	11407	99347	13139	99133	14867	98889	16591	98614	27	2
16	34	097	99528	11436	99344	13168	99129	14896	98884	1662	98609	26	2
17	35	09729	99526	11465	99341	13197	99125	14925	9888	16648	98604	25	2
17	36	09758	99523	11494	99337	13226	99122	14954	98876	16677	986	24	2
18	37	09787	9952	11523	99334	13254	99118	14982	98871	16706	98595	23	2
18	38	09816	99517	11552	99331	13283	99114	15011	98867	16734	9859	22	1
19	39	09845	99514	1158	99327	13312	9911	1504	98863	16763	98585	21	1
19	40	09874	99511	11609	99324	13341	99106	15069	98858	16792	9858	20	1
20	41	09903	99508	11638	9932	1337	99102	15097	98854	1682	98575	19	1
20	42	09932	99506	11667	99317	13399	99098	15126	98849	16849	9857	18	1
21	43	09961	99503	11696	99314	13427	99094	15155	98845	16878	98565	17	1
21	44	0999	995	11725	9931	13456	99091	15184	98841	16906	98561	16	1
22	45	10019	99497	11754	99307	13485	99087	15212	98836	16935	98556	15	1
22	46	10048	99494	11783	99303	13514	99083	15241	98832	16964	98551	14	1
23	47	10077	99491	11812	993	13543	99079	1527	98827	16992	98546	13	1
23	48	10106	99488	1184	99297	13572	99075	15299	98823	17021	98541	12	1
24	49	10135	99485	11869	99293	136	99171	15327	98818	1705	98536	11	1
24	50	10164	99482	11898	9929	13629	99067	15356	98814	17078	98531	10	1
25	51	10192	99479	11927	99286	13658	99063	15385	98809	17107	98526	9	1
25	52	10221	99476	11956	99283	13687	99059	15414	98805	17136	98521	8	1
26	53	1025	99473	11985	99279	13716	99055	15442	988	17164	98516	7	0
26	54	10279	9947	12014	99276	13744	99051	15471	98796	17193	98511	6	0
27	55	10308	99467	12043	99272	13773	99047	155	98791	17222	98506	5	0
27	56	10337	99464	12071	99269	13802	99043	15529	98787	1725	98501	4	0
28	57	10366	99461	121	99265	13831	99039	15557	98782	17279	98496	3	0
28	58	10395	99458	12129	99262	1386	99035	15586	98778	17308	98491	2	0
29	59	10424	99455	12158	99258	13889	99031	15615	98773	17336	98486	1	0
29	60	10453	99452	12187	99255	13917	99027	15643	98769	17365	98481	0	0
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	′	
		84°		83°		82°		81°		80°			

TABLE OF NATURAL SINES AND COSINES—Continued.

Prop. parts.		10°		11°		12°		13°		14°			Prop. parts.
28	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.	N. sine.	N. cos.	N. sine	N. cos.		6
0	0	17365	98481	19081	98163	20791	97815	22495	97437	24192	9703	60	6
0	1	17393	98476	19109	98157	2082	97809	22523	9743	2422	97023	59	6
1	2	17422	98471	19138	98152	20848	97803	22552	97424	24249	97015	58	6
1	3	17451	98466	19167	98146	20877	97797	2258	97417	24277	97008	57	6
2	4	17479	98461	19195	9814	20905	97791	22608	97411	24305	97001	56	6
2	5	17508	98455	19224	98135	20933	97784	22637	97404	24333	96994	55	6
3	6	17537	9845	19252	98129	20962	97778	22665	97398	24362	96987	54	5
3	7	17565	98445	19281	98124	2099	97772	22693	97391	2439	9698	53	5
4	8	17594	9844	19309	98118	21019	97766	22722	97384	24418	96973	52	5
4	9	17623	98435	19338	98112	21047	9776	2275	97378	24446	96966	51	5
5	10	17651	9843	19366	98107	21076	97754	22778	97371	24474	96959	50	5
5	11	1768	98425	19395	95101	21104	97748	22807	97365	24503	96952	49	5
6	12	17708	9842	19423	98096	21132	97742	22835	97358	24531	96945	48	5
6	13	17737	98414	19452	9809	21161	97735	22863	97351	24559	96937	47	5
7	14	17766	98409	19481	98084	21189	97729	22892	97345	24587	9693	46	5
7	15	17794	98404	19509	98079	21218	97723	2292	97338	24615	96923	45	5
7	16	17823	98399	19538	98073	21246	97717	22948	97331	24644	96916	44	4
8	17	17852	98394	19566	98067	21275	97711	22977	97325	24672	96909	43	4
8	18	1788	98389	19595	98061	21303	97705	23005	97318	247	96902	42	4
9	19	17909	98383	19623	98056	21331	97698	23033	97311	24728	96894	41	4
9	20	17937	98378	19652	9805	2136	97692	23062	97304	24756	96887	40	4
10	21	17966	98373	1968	98044	21388	97686	2309	97298	24784	9688	39	4
10	22	17995	98368	19709	98039	21417	9768	23118	97291	24813	96873	38	4
11	23	18023	98362	19737	98033	21445	97673	23146	97284	24841	96866	37	4
11	24	18052	98357	19766	98027	21474	97667	23175	97278	24869	96858	36	4
12	25	18081	98352	19794	98021	21502	97661	23203	97271	24897	96851	35	4
12	26	18109	98347	19823	98016	2153	97655	23231	97264	24925	96844	34	3
13	27	18138	98341	19851	9801	21559	97648	2326	97257	24954	96837	33	3
13	28	18166	98336	1988	98004	21587	97642	23288	97251	24982	96829	32	3
14	29	18195	98331	19908	97998	21616	97636	23316	97244	2501	96822	31	3
14	30	18224	98325	19937	97992	21644	9763	23345	97237	25038	96815	30	3
14	31	18252	9832	19965	97987	21672	97623	23373	9723	25066	96807	29	3
15	32	18281	98315	19994	97981	21701	97617	23401	97223	25094	968	28	3
15	33	18309	9831	20022	97975	21729	97611	23429	97217	25122	96793	27	3
16	34	18338	98304	20051	97969	21758	97604	23458	9721	25151	96786	26	3
16	35	18367	98299	20079	97963	21786	97598	23486	97203	25179	96778	25	3
17	36	18395	98294	20108	97958	21814	97592	23514	97196	25207	96771	24	2
17	37	18424	98288	20136	97952	21843	97585	23542	97189	25235	96764	23	2
18	38	18452	98283	20165	97946	21871	97579	23571	97182	25263	96756	22	2
18	39	18481	98277	20193	9794	21899	97573	23599	97176	25291	96749	21	2
19	40	18509	98272	20222	97934	21928	97566	23627	97169	2532	96742	20	2
19	41	18538	98267	2025	97928	21956	9756	23656	97162	25348	96734	19	2
20	42	18567	98261	20279	97922	21985	97553	23684	97155	25376	96727	18	2
20	43	18595	98256	20307	97916	22013	97547	23712	97148	25404	96719	17	2
21	44	18624	9825	20336	9791	22041	97541	2374	97141	25432	96712	16	2
21	45	18652	98245	20364	97905	2207	97534	23769	97134	2546	96705	15	2
21	46	18681	9824	20393	97899	22098	97528	23797	97127	25488	96697	14	1
22	47	1871	98234	20421	97893	22126	97521	23825	9712	25516	9669	13	1
22	48	18738	98229	2045	97887	22155	97515	23853	97113	25545	96682	12	1
23	49	18767	98223	20478	97881	22183	97508	23882	97106	25573	96675	11	1
23	50	18795	98218	20507	97875	22212	97502	2391	971	25601	96667	10	1
24	51	18824	98212	20535	97869	2224	97496	23938	97093	25629	9666	9	1
24	52	18852	98207	20563	97863	22268	97489	23966	97086	25657	96653	8	1
25	53	18881	98201	20592	97857	22297	97483	23995	97079	25685	96645	7	1
25	54	1891	98196	2062	97851	22325	97476	24023	97072	25713	96638	6	1
26	55	18938	98190	20649	97845	22353	9747	24051	97065	25741	9663	5	1
26	56	18967	98185	20677	97839	22382	97463	24079	97058	25769	96623	4	0
27	57	18995	98179	20706	97833	2241	97457	24108	97051	25798	96615	3	0
27	58	19024	98174	20734	97827	22438	9745	24136	97044	25826	96608	2	0
28	59	19052	98168	20763	97821	22467	97444	24164	97037	25854	966	1	0
28	60	19081	98163	20791	97815	22495	97437	24192	9703	25882	96593	0	0
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	′	
		79°		78°		77°		76°		75°			

TABLE OF NATURAL SINES AND COSINES—Continued.

Prop. parts.		15°		16°		17°		18°		19°			Prop. parts.
27	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.	N. sine.	N. cos.	N. sine	N. cos.		9
0	0	25882	96593	27564	96126	29237	9563	30902	95106	32557	94552	60	9
0	1	2591	96585	27592	96118	29265	95622	30929	95097	32584	94542	59	9
1	2	25938	96578	2762	9611	29293	95613	30957	95088	32612	94533	58	9
1	3	25966	9657	27648	96102	29321	95605	30985	95079	32639	94523	57	9
2	4	25994	96562	27676	96094	29348	95596	31012	9507	32667	94514	56	8
2	5	26022	96555	27704	96086	29376	95588	3104	95061	32694	94504	55	8
3	6	2605	96547	27731	96078	29404	95579	31068	95052	32722	94495	54	8
3	7	26079	9654	27759	9607	29432	95571	31095	95043	32749	94485	53	8
4	8	26107	96532	27787	96062	2946	95562	31123	95033	32777	94476	52	8
4	9	26135	96524	27815	96054	29487	95554	31151	95024	32804	94466	51	8
5	10	26163	96517	27843	96046	29515	95545	31178	95015	32832	94457	50	8
5	11	26191	96509	27871	96037	29543	95536	31206	95006	32859	94447	49	7
5	12	26219	96502	27899	96029	29571	95528	31233	94997	32887	94438	48	7
6	13	26247	96494	27927	96021	29599	95519	31261	94988	32914	94428	47	7
6	14	26275	96486	27955	96013	29626	95511	31289	94979	32942	94418	46	7
7	15	26303	96479	27983	96005	29654	95502	31316	9497	32969	94409	45	7
7	16	26331	96471	28011	95997	29682	95493	31344	94961	32997	94399	44	7
8	17	26359	96463	28039	95989	2971	95485	31372	94952	33024	9439	43	6
8	18	26387	96456	28067	95981	29737	95476	31399	94943	33051	9438	42	6
9	19	26415	96448	28095	95972	29765	95467	31427	94933	33079	9437	41	6
9	20	26443	9644	28123	95964	29793	95459	31454	94924	33106	94361	40	6
9	21	26471	96433	2815	95956	29821	9545	31482	94915	33134	94351	39	6
10	22	265	96425	28178	95948	29849	95441	3151	94906	33161	94342	38	6
10	23	26528	96417	28206	9594	29876	95433	31537	94897	33189	94332	37	6
11	24	26556	9641	28234	95931	29904	95422	31565	94888	33216	94322	36	5
11	25	26584	96402	28262	95923	29932	95415	31593	94878	33244	94313	35	5
12	26	26612	96394	2829	95915	2996	95407	3162	94869	33271	94303	34	5
12	27	2664	96386	28318	95907	29987	95398	31648	9486	33298	94293	33	5
13	28	26668	96379	28346	95898	30015	95389	31675	94851	33326	94284	32	5
13	29	26696	96371	28374	9589	30043	9538	31703	94842	33353	94274	31	5
14	30	26724	96363	28402	95882	30071	95372	3173	94832	33381	94264	30	5
14	31	26752	96355	28429	95874	30098	95363	31758	94823	33408	94254	29	4
14	32	2678	96347	28457	95865	30126	95354	31786	94814	33436	94245	28	4
15	33	26808	9034	28485	95857	30154	95345	31813	94805	33463	94235	27	4
15	34	26836	96332	28513	95849	30182	95337	31841	94795	3349	94225	26	4
16	35	26864	96324	28541	95841	30209	95328	31868	94786	33518	94215	25	4
16	36	26892	96316	28569	95832	30237	95319	31896	94777	33545	94206	24	4
17	37	2692	96308	28597	95824	30265	9531	31923	94768	33573	94196	23	3
17	38	26948	96301	28625	95816	30292	95301	31951	94758	336	94186	22	3
18	39	26976	96293	28652	95807	3032	95293	31979	94749	33627	94176	21	3
18	40	27004	96285	2868	95799	30348	95284	32006	9474	33655	94167	20	3
18	41	27032	96277	28708	95791	30376	95275	32034	9473	33682	94157	19	3
19	42	2706	96269	28736	95782	30403	95266	32061	94721	3371	94147	18	3
19	43	27088	96261	28764	95774	30431	95257	32089	94712	33737	94137	17	3
20	44	27116	96253	28792	95766	30459	95248	32116	94702	33764	94127	16	2
20	45	27144	96246	2882	95757	30486	9524	32144	94693	33792	94118	15	2
21	46	27172	96238	28847	95749	30514	95231	32171	94684	33819	94108	14	2
21	47	272	9623	28875	9574	30542	95222	32199	94674	33846	94098	13	2
22	48	27228	96222	28903	95732	3057	95213	32227	94665	33874	94088	12	2
22	49	27256	96214	28931	95724	30597	95204	32254	94656	33901	94078	11	2
23	50	27284	96206	28959	95715	30625	95195	32282	94646	33929	94068	10	2
23	51	27312	96198	28987	95707	30653	95186	32309	94637	33956	94058	9	1
23	52	2734	9619	29015	95698	3068	95177	32337	94627	33983	94049	8	1
24	53	27368	96182	29042	9569	30708	95168	32364	94618	34011	94039	7	1
24	54	27396	96174	2907	95681	30736	95159	32392	94609	34038	94029	6	1
25	55	27424	96166	29098	95673	30763	9515	32419	94599	34065	94019	5	1
25	56	27452	96158	29126	95664	30791	95142	32447	9459	34093	94009	4	1
26	57	2748	9615	29154	95656	30819	95133	32474	9458	3412	93999	3	0
26	58	27508	96142	29182	95647	30846	95124	32502	94571	34147	93989	2	0
27	59	27536	96134	29209	95639	30874	95115	32529	94561	34175	93979	1	0
27	60	27564	96126	29237	9563	30902	95106	32557	94552	34202	93969	0	0
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	′	
		74°		73°		72°		71°		70°			

TABLE OF NATURAL SINES AND COSINES—Continued.

Prop. parts.		20°		21°		22°		23°		24°			Prop. parts.
27	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.	N. sine.	N. cos.	N. sine	N. cos		11
0	0	34202	93969	35837	93358	37461	92718	39073	9205	40674	91355	60	11
0	1	34229	93959	35864	93348	37488	92707	391	92039	407	91343	59	11
1	2	34257	93949	35891	93337	37515	92697	39127	92028	40727	91331	58	11
1	3	34284	93939	35918	93327	37542	92686	39153	92016	40753	91319	57	10
2	4	34311	93929	35945	93316	37569	92675	3918	92005	4078	91307	56	10
2	5	34339	93919	35973	93306	37595	92664	39207	91994	40806	91295	55	10
3	6	34366	93909	36	93295	37622	92653	39234	91982	40833	91283	54	10
3	7	34393	93899	36027	93285	37649	92642	3926	91971	4086	91272	53	10
4	8	34421	93889	36054	93274	37676	92631	39287	91959	40886	9126	52	10
4	9	34448	93879	36081	93264	37703	9262	39314	91948	40913	91248	51	9
5	10	34475	93869	36108	93253	3773	92609	39341	91936	40939	91236	50	9
5	11	34503	93859	36135	93243	37757	92598	39367	91925	40966	91224	49	9
5	12	3453	93849	36162	93232	37784	92587	39394	91914	40992	91212	48	9
6	13	34557	93839	3619	93222	37811	92576	39421	91902	41019	912	47	9
6	14	34584	93829	36217	93211	37838	92565	39448	91891	41045	91188	46	8
7	15	34612	93819	36244	93201	37865	92554	39474	91879	41072	91176	45	8
7	16	34639	93809	36271	9319	37892	92543	39501	91868	41098	91164	44	8
8	17	34666	93799	36298	9318	37919	92532	39528	91856	41125	91152	43	8
8	18	34694	93789	36325	93169	37946	92521	39555	91845	41151	9114	42	8
9	19	34721	93779	36352	93159	37973	9251	39581	91833	41178	91128	41	8
9	20	34748	93769	36379	93148	37999	92499	39608	91822	41204	91116	40	7
9	21	34775	93759	36406	93137	38026	92488	39635	9181	41231	91104	39	7
10	22	34803	93748	36434	93127	38053	92477	39661	91799	41257	91092	38	7
10	23	3483	93738	36461	93116	3808	92466	39688	91787	41284	9108	37	7
11	24	34857	93728	36488	93106	38107	92455	39715	91775	4131	91068	36	7
11	25	34884	93718	36515	93095	38134	92444	39741	91764	41337	91056	35	6
12	26	34912	93708	36542	93084	38161	92432	39768	91752	41363	91044	34	6
12	27	34939	93698	36569	93074	38188	92421	39795	91741	4139	91032	33	6
13	28	34966	93688	36596	93063	38215	9241	39822	91729	41416	9102	32	6
13	29	34993	93677	36623	93052	38241	92399	39848	91718	41443	91008	31	6
14	30	35021	93667	3665	93042	38268	92388	39875	91706	41469	90996	30	6
14	31	35048	93657	36677	93031	38295	92377	39902	91694	41496	90984	29	5
14	32	35075	93647	36704	9302	38322	92366	39928	91683	41522	90972	28	5
15	33	35102	93637	36731	9301	38349	92355	39955	91671	41549	9096	27	5
15	34	3513	93626	36758	92999	38376	92343	39982	9166	41575	90948	26	5
16	35	35157	93616	36785	92988	38403	92332	40008	91648	41602	90936	25	5
16	36	35184	93606	36812	92978	3843	92321	40035	91636	41628	90924	24	4
17	37	35211	93596	36839	92967	38456	9231	40062	91625	41655	90911	23	4
17	38	35239	93585	36867	92956	38483	92299	40088	91613	41681	90899	22	4
18	39	35266	93575	36894	92945	3851	92287	40115	91601	41707	90887	21	4
18	40	35293	93565	36921	92935	38537	92276	40141	9159	41734	90875	20	4
18	41	3532	93555	36948	92924	38564	92265	40168	91578	4176	90863	19	3
19	42	35347	93544	36975	92913	38591	92254	40195	91566	41787	90851	18	3
19	43	35375	93534	37002	92902	38617	92243	40221	61555	41813	90839	17	3
20	44	35402	93524	37029	92892	38644	92231	40248	91543	4184	90826	16	3
20	45	35429	93514	37056	92881	38671	9222	40275	91531	41866	90814	15	3
21	46	35456	93503	37083	9287	38698	92209	40301	91519	41892	90802	14	3
21	47	35484	93493	3711	92859	38725	92198	40328	91508	41919	9079	13	2
22	48	35511	93483	37137	92849	38752	92186	40355	91496	41945	90778	12	2
22	49	35538	93472	37164	92838	38778	92175	40381	91484	41972	90766	11	2
23	50	35565	93462	37191	92827	38805	92164	40408	91472	41998	90753	10	2
23	51	35592	93452	37218	92816	38832	92152	40434	91461	42024	90741	9	2
23	52	35619	93441	37245	92805	38859	92141	40461	91449	42051	90729	8	1
24	53	35647	93431	37272	92794	38886	9213	40488	91437	42077	90717	7	1
24	54	35674	9342	37299	92784	38912	92119	40514	91425	42104	90704	6	1
25	55	35701	9341	37326	92773	38939	92107	40541	91414	4213	90692	5	1
25	56	35728	934	37353	92762	38966	92096	40567	91402	42156	9068	4	1
26	57	35755	93389	3738	92751	38993	92085	40594	9139	42183	90668	3	1
26	58	35782	93379	37407	9274	3902	92073	40621	91378	42209	90655	2	0
27	59	3581	93368	37434	92729	39046	92062	40647	91366	42235	90643	1	0
27	60	35837	93358	37461	92718	39073	9205	40674	91355	0	0
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos	N. sine	′	
		69°		68°		67°		66°		65°			

Prop. parts.		25°		26°		27°		28°		29°			Prop. parts.
26	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.		11
0	0	42262	90631	43837	89879	45399	89101	46947	88295	48481	87462	60	14
0	1	42288	90618	43863	89867	45425	89087	46973	88281	48506	87448	59	14
1	2	42315	90606	43889	89854	45451	89074	46999	88267	48532	87434	58	14
1	3	42341	90594	43916	89841	45477	89061	47024	88254	48557	8742	57	13
2	4	42367	90582	43942	89828	45503	89048	4705	8824	48583	87406	56	13
2	5	42394	90569	43968	89816	45529	89035	47076	88226	48608	87391	55	13
3	6	4242	90557	43994	89803	45554	89021	47101	88213	48634	87377	54	13
3	7	42446	90545	4402	8979	4558	89008	47127	88199	48659	87363	53	12
3	8	42473	90532	44046	89777	45606	88995	47153	88185	48684	87349	52	12
4	9	42499	9052	44072	89764	45632	88981	47178	88172	4871	87335	51	12
4	10	42525	90507	44098	89752	45658	88968	47204	88158	48735	87321	50	12
5	11	42552	90495	44124	89739	45684	88955	47229	88144	48761	87306	49	11
5	12	42578	90483	44151	89726	4571	88942	47255	8813	48786	87292	48	11
6	13	42604	9047	44177	89713	45736	88928	47281	88117	48811	87278	47	11
6	14	42631	90458	44203	897	45762	88915	47306	88103	48837	87264	46	11
7	15	42657	90446	44229	89687	45787	88902	47332	88089	48862	8725	45	11
7	16	42683	90433	44255	89674	45813	88888	47358	88075	48888	87235	44	10
7	17	42709	90421	44281	89662	45839	88875	47383	88062	48913	87221	43	10
8	18	42736	90408	44307	89649	45865	88862	47409	88048	48938	87207	42	10
8	19	42762	90396	44333	89636	45891	88848	47434	88034	48964	87193	41	10
9	20	42788	90383	44359	89623	45917	88835	4746	8802	48989	87178	40	9
9	21	42815	90371	44385	8961	45942	88822	47486	88006	49014	87164	39	9
10	22	42841	90358	44411	89597	45968	88808	47511	87993	4904	8715	38	9
10	23	42867	90346	44437	89584	45994	88795	47537	87979	49065	87136	37	9
10	24	42894	90334	44464	89571	4602	88782	47562	87965	4909	87121	36	8
11	25	4292	90321	4449	89558	46046	88768	47588	87951	49116	87107	35	8
11	26	42946	90309	44516	89545	46072	88755	47614	87937	49141	87093	34	8
12	27	42972	90296	44542	89532	46097	88741	47639	87923	49166	87079	33	8
12	28	42999	90284	44568	89519	46123	88728	47665	87909	49192	87064	32	7
13	29	43025	90271	44594	89506	46149	88715	4769	87896	49217	8705	31	7
13	30	43051	90259	4462	89493	46175	88701	47716	87882	49242	87036	30	7
13	31	43077	90246	44646	8948	46201	88688	47741	87868	49268	87021	29	7
14	32	43104	90233	44672	89467	46226	88674	47767	87854	49293	87007	28	7
14	33	4313	90221	44698	89454	46252	88661	47793	8784	49318	86993	27	6
15	34	43156	90208	44724	89441	46278	88647	47818	87826	49344	86978	26	6
15	35	43182	90196	4475	89428	46304	88634	47844	87812	49369	86964	25	6
16	36	43209	90183	44776	89415	4633	8862	47869	87798	49394	86949	24	6
16	37	43235	90171	44802	89402	46355	88607	47895	87784	49419	86935	23	5
16	38	43261	90158	44828	89389	46381	88593	4792	8777	49445	86921	22	5
17	39	43287	90146	44854	89376	46407	8858	47946	87756	4947	86906	21	5
17	40	43313	90133	4488	89363	46433	88566	47971	87743	49495	86892	20	5
18	41	4334	9012	44906	8935	46458	88553	47997	87729	49521	86878	19	4
18	42	43366	90108	44932	89337	46484	88539	48022	87715	49546	86863	18	4
19	43	43392	90095	44958	89324	4651	88526	48048	87701	49571	86849	17	4
19	44	43418	90082	44984	89311	46536	88512	48073	87687	49596	86834	16	4
20	45	43445	9007	4501	89298	46561	88499	48099	87673	49622	8682	15	4
20	46	43471	90057	45036	89285	46587	88485	48124	87659	49647	86805	14	3
20	47	43497	90045	45062	89272	46613	88472	4815	87645	49672	86791	13	3
21	48	43523	90032	45088	89259	46639	88458	48175	87631	49697	86777	12	3
21	49	43540	90019	45114	89245	46664	88445	48201	87617	49723	86762	11	3
22	50	43575	90007	4514	89232	4669	88431	48226	87603	49748	86748	10	2
22	51	43602	89994	45166	89219	46716	88417	48252	87589	49773	86733	9	2
23	52	43628	89981	45192	89206	46742	88404	48277	87575	49798	86719	8	2
23	53	43654	89968	45218	89193	46767	8839	48303	87561	49824	86704	7	2
23	54	4368	89956	45243	8918	46793	88377	48328	87546	49849	8669	6	1
24	55	43706	89943	45269	89167	46819	88363	48354	87532	49874	86675	5	1
24	56	43733	8993	45295	89153	46844	88349	48379	87518	49899	86661	4	1
25	57	43759	89918	45321	8914	4687	88336	48405	87504	49924	86646	3	1
25	58	43785	89905	45347	89127	46896	88322	4843	8749	4995	86632	2	0
26	59	43811	89892	45373	89114	46921	88308	48456	87476	49975	86617	1	0
26	60	43837	89879	45399	89101	46947	88295	48481	87462	5	86603	0	0
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos	N. sine	′	
		64°		63°		62°		61°		60°			

TABLE OF NATURAL SINES AND COSINES—Continued.

Prop. parts.		30°		31°		32°		33°		34°			Prop. parts.
25	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.		11
0	0	5	86603	51504	85717	52992	84805	54464	83867	55919	82904	60	16
0	1	50025	86588	51529	85702	53017	84789	54488	83851	55943	82887	59	16
1	2	5005	86573	51554	85687	53041	84774	54513	83835	55968	82871	58	15
1	3	50076	86559	51579	85672	53066	84759	54537	83819	55992	82855	57	15
2	4	50101	86544	51604	85657	53091	84743	54561	83804	56016	82839	56	15
2	5	50126	8653	51628	85642	53115	84728	54586	83788	5604	82822	55	15
3	6	50151	86515	51653	85627	5314	84712	5461	83772	56064	82806	54	14
3	7	50176	86501	51678	85612	53164	84697	54635	83756	56088	8279	53	14
3	8	50201	86486	51703	85597	53189	84681	54659	8374	56112	82773	52	14
4	9	50227	86471	51728	85582	53214	84666	54683	83724	56136	82757	51	14
4	10	50252	86457	51753	85567	53238	8465	54708	83708	5616	82741	50	13
5	11	50277	86442	51778	85551	53263	84635	54732	83692	56184	82724	49	13
5	12	50302	86427	51803	85536	53288	84619	54756	83676	56208	82708	48	13
5	13	50327	86413	51828	85521	53312	84604	54781	8366	56232	82692	47	13
6	14	50352	86398	51852	85506	53337	84588	54805	83645	56256	82675	46	12
6	15	50377	86384	51877	85491	53361	84573	54829	83629	5628	82659	45	12
7	16	50403	86369	51902	85476	53386	84557	54854	83613	56305	82643	44	12
7	17	50428	86354	51927	85461	53411	84542	54878	83597	56329	82626	43	11
8	18	50453	8634	51952	85446	53435	84526	54902	83581	56353	8261	42	11
8	19	50478	86325	51977	85431	5346	84511	54927	83565	56377	82593	41	11
8	20	50503	8631	52002	85416	53484	84495	54951	83549	56401	82577	40	11
9	21	50528	86295	52026	85401	53509	8448	54975	83533	56425	82561	39	10
9	22	50553	86281	52051	85385	53534	84464	54999	83517	56449	82544	38	10
10	23	50578	86266	52076	8537	53558	84448	55024	83501	56473	82528	37	10
10	24	50603	86251	52101	85355	53583	84433	55048	83485	56497	82511	36	10
10	25	50628	86237	52126	8534	53607	84417	55072	83469	56521	82495	35	9
11	26	50654	86222	52151	85325	53632	84402	55097	83453	56545	82478	34	9
11	27	50679	86207	52175	8531	53656	84386	55121	83437	56569	82462	33	9
12	28	50704	86192	522	85294	53681	8437	55145	83421	56593	82446	32	9
12	29	50729	86178	52225	85279	53705	84355	55169	83405	56617	82429	31	8
13	30	50754	86163	5225	85264	5373	84339	55194	83389	56641	82413	30	8
13	31	50779	86148	52275	85249	53754	84324	55218	83373	56665	82396	29	8
13	32	50804	86133	52299	85234	53779	84308	55242	83356	56689	8238	28	7
14	33	50829	86119	52324	85218	53804	84292	55266	8334	56713	82363	27	7
14	34	50854	86104	52349	85203	53828	84277	55291	83324	56736	82347	26	7
15	35	50879	86089	52374	85188	53853	84261	55315	83308	5676	8233	25	7
15	36	50904	86074	52399	85173	53877	84245	55339	83292	56784	82314	24	6
15	37	50929	86059	52423	85157	53902	8423	55363	83276	56808	82297	23	6
16	38	50954	86045	52448	85142	53926	84214	55388	8326	56832	82281	22	6
16	39	50979	8603	52473	85127	53951	84198	55412	83244	56856	82264	21	6
17	40	51004	86015	52498	85112	53975	84182	55436	83228	5688	82248	20	5
17	41	51029	86	52522	85096	54	84167	5546	83212	56904	82231	19	5
18	42	51054	85985	52547	85081	54024	84151	55484	83195	56928	82214	18	5
18	43	51079	8597	52572	85066	54049	84135	55509	83179	56952	82198	17	5
18	44	51104	85956	52597	85051	54073	8412	55533	83163	56976	82181	16	4
19	45	51129	85941	52621	85035	54097	84104	55557	83147	57	82165	15	4
19	46	51154	85926	52646	8502	54122	84088	55581	83131	57024	82148	14	4
20	47	51179	85911	52671	85005	54146	84072	55605	83115	57047	82132	13	3
20	48	51204	85896	52696	84989	54171	84057	5563	83098	57071	82115	12	3
20	49	51229	85881	5272	84974	54195	84041	55654	83082	57095	82098	11	3
21	50	51254	85866	52745	84959	5422	84025	55678	83066	57119	82082	10	3
21	51	51279	85851	5277	84943	54244	84009	55702	8305	57143	82065	9	2
22	52	51304	85836	52794	84928	54269	83994	55726	83034	57167	82048	8	2
22	53	51329	85821	52819	84913	54293	83978	5575	83017	57191	82032	7	2
23	54	51354	85806	52844	84897	54317	83962	55775	83001	57215	82015	6	2
23	55	51379	85792	52869	84882	54342	83946	55799	82985	57238	81999	5	1
23	56	51404	85777	52893	84866	54366	8393	55823	82969	57262	81982	4	1
24	57	51429	85762	52918	84851	54391	83915	55847	82953	57286	81965	3	1
24	58	51454	85747	52943	84836	54415	83899	55871	82936	5731	81949	2	1
25	59	51479	85732	52967	8482	5444	83883	55895	8292	57334	81932	1	0
25	60	51504	75717	52992	84805	54464	83867	55919	82904	57358	81915	0	0
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine		
		59°		58°		57°		56°		55°			

TABLE OF NATURAL SINES AND COSINES—Continued.

Prop. parts.		35°		36°		37°		38°		39°			Prop. parts.
25	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.		18
0	0	57358	81915	58779	80902	60182	79864	61566	78801	62932	77715	60	18
0	1	57381	81899	58802	80885	60205	79846	61589	78783	62955	77696	59	18
1	2	57405	81882	58826	80867	60228	79829	61612	78765	62977	77678	58	17
1	3	57429	81865	58849	8085	60251	79811	61635	78747	63	7766	57	17
2	4	57453	81848	58873	80833	60274	79793	61658	78729	63022	77641	56	17
2	5	57477	81832	58896	80816	60298	79776	61681	78711	63045	77623	55	17
2	6	57501	81815	5892	80799	60321	79758	61704	78694	63068	77605	54	16
3	7	57524	81798	58943	80782	60344	79741	61726	78676	6309	77586	53	16
3	8	57548	81782	58967	80765	60367	79723	61749	78658	63113	77568	52	16
3	9	57572	81765	5899	80748	6039	79706	61772	7864	63135	7755	51	15
4	10	57596	81748	59014	80730	60414	79688	61795	78622	63158	77531	50	15
4	11	57619	81731	59037	80713	60437	79671	61818	78604	6318	77513	49	15
5	12	57643	81714	59061	80696	6046	79653	61841	78586	63203	77494	48	14
5	13	57667	81698	59084	80679	60483	79635	61864	78568	63225	77476	47	14
5	14	57691	81681	59108	80662	60506	79618	61887	7855	63248	77458	46	14
6	15	57715	81664	59131	80644	60529	796	61909	78532	63271	77439	45	14
6	16	57738	81647	59154	80627	60553	79583	61932	78514	63293	77421	44	13
7	17	57762	81631	59178	8061	60576	79565	61955	78496	63316	77402	43	13
7	18	57786	81614	59201	80593	60509	79547	61978	78478	63338	77384	42	13
7	19	5781	81597	59225	80576	60622	7953	62001	7846	63361	77366	41	12
8	20	57833	8158	59248	80558	60645	79512	62024	78442	63383	77347	40	12
8	21	57857	81563	59272	80541	60668	79494	62046	78424	63406	77329	39	12
8	22	57881	81546	59295	80524	60691	79477	62069	78405	63428	7731	38	11
9	23	57904	8153	59318	80507	60714	79459	62092	78387	63451	77292	37	11
9	24	57928	81513	59342	80489	60738	79441	62115	78369	63473	77273	36	11
10	25	57952	81496	59365	80472	60761	79424	62138	78351	63496	77255	35	11
10	26	57976	81479	59389	80455	60784	79406	6216	78333	63518	77236	34	10
10	27	57999	81462	59412	80438	60807	79388	62183	78315	6354	77218	33	10
11	28	58023	81445	59436	8042	6083	79371	62206	78297	63563	77199	32	10
11	29	58047	81428	59459	80403	60853	79353	62229	78279	63585	77181	31	9
12	30	5807	81412	59482	80386	60876	79335	62251	78261	63608	77162	30	9
12	31	58094	81395	59506	80368	60899	79318	62274	78243	6363	77144	29	9
12	32	58118	81378	59529	80351	60922	793	62297	78225	63653	77125	28	8
13	33	58141	81361	59552	80334	60945	79282	6232	78206	63675	77107	27	8
13	34	58165	81344	59576	80316	60968	79264	62342	78188	63698	77088	26	8
13	35	58189	81327	59599	80299	60991	79247	62365	7817	6372	7707	25	8
14	36	58212	8131	59622	80282	61015	79229	62388	78152	63742	77051	24	7
14	37	58236	81293	59646	80264	61038	79211	62411	78134	63765	77033	23	7
15	38	5826	81276	59669	80247	61061	79193	62433	78116	63787	77014	22	7
15	39	58283	81259	59693	8023	61084	79176	62456	78098	6381	76996	21	6
15	40	58307	81242	59716	80212	61107	79158	62479	78079	63832	76977	20	6
16	41	5833	81225	59739	80195	6113	7914	62502	78061	63854	76959	19	6
16	42	58354	81208	59763	80178	61153	79122	62524	78043	63877	7694	18	5
16	43	58378	81191	59786	8016	61176	79105	62547	78025	63899	76921	17	5
17	44	58401	81174	59809	80143	61199	79087	6257	78007	63922	76903	16	5
17	45	58425	81157	59832	80125	61222	79069	62592	77988	63944	76884	15	5
18	46	58440	8114	59856	80108	61245	79051	62615	7797	63966	76866	14	4
18	47	58472	81123	59879	80091	61268	79033	62638	77952	63989	76847	13	4
18	48	58496	81106	59902	80073	61291	79016	6266	77934	64011	76828	12	4
19	49	58519	81089	59926	80056	61314	78998	62683	77916	64033	7681	11	3
19	50	58543	81072	59949	80038	61337	7898	62706	77897	64056	76791	10	3
20	51	58567	81055	59972	80021	6136	78962	62728	77879	64078	76772	9	3
20	52	5859	81038	59995	80003	61383	78944	62751	77861	641	76754	8	2
20	53	58614	81021	60019	79986	61406	78926	62774	77843	64123	76735	7	2
21	54	58637	81004	60042	79968	61429	78908	62796	77824	64145	76717	6	2
21	55	58661	80987	60065	79951	61451	78891	62819	77806	64167	76698	5	2
21	56	58684	8097	60089	79934	61474	78873	62842	77788	6419	76679	4	1
22	57	58708	80953	60112	79916	61497	78855	62864	77769	64212	76661	3	1
22	58	58731	80936	60135	79899	6152	78837	62887	77751	64234	76642	2	1
23	59	58755	80919	60158	79881	61543	78819	62909	77733	64256	76623	1	0
23	60	58779	80902	60182	79864	61566	78801	62932	77715	64279	76604	0	0
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.	N. sine	′	
		54°		53°		52°		51°		50°			

TABLE OF NATURAL SINES AND COSINES—Concluded.

Prop. parts.		40°		41°		42°		43°		44°			Prop. parts.
22	′	N. sine	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	N. cos.		19
0	0	64279	76604	65606	75471	66913	74314	682	73135	69466	71934	60	19
0	1	64301	76586	65628	75452	66935	74295	68221	73116	69487	71914	59	19
1	2	64323	76567	6565	75433	66956	74276	68242	73096	69508	71894	58	18
1	3	64346	76548	65672	75414	66978	74256	68264	73076	69529	71873	57	18
1	4	64368	7653	65694	75395	66999	74237	68285	73056	69549	71853	56	18
2	5	6439	76511	65716	75375	67021	74217	68306	73036	6957	71833	55	17
2	6	64412	76492	65738	75356	67043	74198	68327	73016	69591	71813	54	17
3	7	64435	76473	65759	75337	67064	74178	68349	72996	69612	71792	53	17
3	8	64457	76455	65781	75318	67086	74159	6837	72976	69633	71772	52	16
3	9	64479	76436	65803	75299	67107	74139	68391	72957	69654	71752	51	16
4	10	64501	76417	65825	7528	67129	7412	68412	72937	69675	71732	50	16
4	11	64524	76398	65847	75261	67151	741	68434	72917	69696	71711	49	16
4	12	64546	7638	65869	75241	67172	7408	68455	72897	69717	71691	48	15
5	13	64568	76361	65891	75222	67194	74061	68476	72877	69737	71671	47	15
5	14	6459	76342	65913	75203	67215	74041	68497	72857	69758	7165	46	15
6	15	64612	76323	65935	75184	67237	74022	68518	72837	69779	7163	45	14
6	16	64635	76304	65956	75165	67258	74002	68539	72817	698	7161	44	14
6	17	64657	76286	65978	75146	6728	73983	68561	72797	69821	7159	43	14
7	18	64679	76267	66	75126	67301	73963	68582	72777	69842	71569	42	13
7	19	64701	76248	66022	75107	67323	73944	68603	72757	69862	71549	41	13
7	20	64723	76229	66044	75088	67344	73924	68624	72737	69883	71529	40	13
8	21	64746	7621	66066	75069	67366	73904	68645	72717	69904	71508	39	12
8	22	64768	76192	66088	7505	67387	73885	68666	72697	69925	71488	38	12
8	23	6479	76173	66109	7503	67409	73865	68688	72677	69946	71468	37	12
9	24	64812	76154	66131	75011	6743	73846	68709	72657	69966	71447	36	11
9	25	64834	76135	66153	74992	67452	73826	6873	72637	69987	71427	35	11
10	26	64856	76116	66175	74973	67473	73806	68751	72617	70008	71407	34	11
10	27	64878	76097	66197	74953	67495	73787	68772	72597	70029	71386	33	10
10	28	64901	76078	66218	74934	67516	73767	68793	72577	70049	71366	32	10
11	29	64923	76059	6624	74915	67538	73747	68814	72557	7007	71345	31	10
11	30	64945	76041	66262	74896	67559	73728	68835	72537	70091	71325	30	10
11	31	64967	76022	66284	74876	6758	73708	68857	72517	70112	71305	29	9
12	32	64989	76003	66306	74857	67602	73688	68878	72497	70132	71284	28	9
12	33	65011	75984	66327	74838	67623	73669	68899	72477	70153	71264	27	9
12	34	65033	75965	66349	74818	67645	73649	6892	72457	70174	71243	26	8
13	35	65055	75946	66371	74799	67666	73629	68941	72437	70195	71223	25	8
13	36	65077	75927	66393	7478	67688	7361	68962	72417	70215	71203	24	8
14	37	651	75908	66414	7476	67709	7359	68983	72397	70236	71182	23	7
14	38	65122	75889	66436	74741	6773	7357	69004	72377	70257	71162	22	7
14	39	65144	7587	66458	74722	67752	73551	69025	72357	70277	71141	21	7
15	40	65166	75851	6648	74703	67773	73531	69046	72337	70298	71121	20	6
15	41	65188	75832	66501	74683	67795	73511	69067	72317	70319	711	19	6
15	42	6521	75813	66523	74664	67816	73491	69088	72297	70339	7108	18	6
16	43	65232	75794	66545	74644	67837	73472	69109	72277	7036	71059	17	5
16	44	65254	75775	66566	74625	67859	73452	6913	72257	70381	71039	16	5
17	45	65276	75756	66588	74606	6788	73432	69151	72236	70401	71019	15	5
17	46	65298	75738	6661	74586	67901	73413	69172	72216	70422	70998	14	4
17	47	6532	75719	66632	74567	67923	73393	69193	72196	70443	70978	13	4
18	48	65342	757	66653	74548	67944	73373	69214	72176	70463	70957	12	4
18	49	65364	7568	66675	74528	67965	73353	69235	72156	70484	70937	11	3
18	50	65386	75661	66697	74509	67987	73333	69256	72136	70505	70916	10	3
19	51	65408	75642	66718	74489	68008	73314	69277	72116	70525	70896	9	3
19	52	6543	75623	6674	7447	68029	73294	69298	72095	70546	70875	8	3
19	53	65452	75604	66762	74451	68051	73274	69319	72075	70567	70855	7	2
20	54	65474	75585	66783	74431	68072	73254	6934	72055	70587	70834	6	2
20	55	65496	75566	66805	74412	68093	73234	69361	72035	70608	70813	5	2
21	56	65518	75547	66827	74392	68115	73215	69382	72015	70628	70793	4	1
21	57	6554	75528	66848	74373	68136	73195	69403	71995	70649	70772	3	1
21	58	65562	75509	6687	74353	68157	73175	69424	71974	7067	70752	2	1
22	59	65584	7549	66891	74334	68179	73155	69445	71954	7069	70731	1	0
22	60	65606	75471	66913	74314	682	73135	69466	71934	70711	70711	0	0
		N. cos	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine	′	
		49°		48°		47°		46°		45°			

The preceding Table contains the Natural Sine and Cosine for every minute of the quadrant to the radius of 1, and although the decimal point is not put in the Table, it is always to be prefixed.

If the Degrees are taken at the head of the columns, the minutes, sine, and cosine must be taken from the head also; and if they are taken at the foot of the column, they must be taken from the foot also.

ILLUSTRATION.—.3173 is the sine of 18° 30′, and the cosine of 71° 30′.

WHEN THE ANGLE EXCEEDS 45°.

Ascertain the sine or cosine for the angle in degrees and minutes from the Table, taking the degrees at the foot of it; then take the difference between it and the sine or cosine of the angle next above it.

Look for the remainder, if the sine is required, at the head of the column of *Proportional Parts*, on the right side; and if the Cosine is required, at the head of the column on the left side; and in these respective columns, opposite to the seconds in the angle, is the number or correction in seconds to be added to the sine, or subtracted from the Cosine of the angle.

EXAMPLE.—What is the sine of 81° 50′ 50″?

$$\left.\begin{array}{l}\text{Sine of } 81^\circ\ 50', \text{ per Table} = .98986; \\ \text{Sine of } 81^\circ\ 51', \quad \text{“} \quad = .98990;\end{array}\right\}\textit{difference}\ .00004.$$

In the right-side column of proportional parts, and opposite to 50′, is 3, which, being added to .98986=.98989, *the sine.*

Ex. 2.—What is the cosine of 81° 50′ 50″?

$$\left.\begin{array}{l}\text{Cosine of } 81^\circ\ 50', \text{ per Table} = .14205; \\ \text{Cosine of } 81^\circ\ 51', \quad \text{“} \quad = .14177;\end{array}\right\}\textit{difference},.00025.$$

In left-side column of proportional parts, and opposite to 50′, is 24, which, being subtracted from .14205=.14181, *the cosine.*

LOGARITHM OF NUMBERS FROM 0 TO 1000.

No.	0	1	2	3	4	5	6	7	8	9	Prop.
0	0	00000	30103	47712	60206	69897	77815	84510	90309	95424	
10	00000	00432	00860	01283	01703	02119	02530	02938	03342	03742	415
11	04139	04532	04921	05307	05690	06069	06445	06818	07188	07554	379
12	07918	08278	08636	08990	09342	09691	10037	10380	10721	11059	344
13	11394	11727	12057	12385	12710	13033	13353	13672	13987	14301	323
14	14613	14922	15228	15533	15836	16136	16435	16731	17026	17318	298
15	17609	17897	18184	18469	18752	19033	19312	19590	19865	20139	281
16	20412	20682	20951	21218	21484	21748	22010	22271	22531	22788	264
17	23045	23299	23552	23804	24054	24303	24551	24797	25042	25285	249
18	25527	25767	26007	26245	26481	26717	26951	27184	27415	27646	234
19	27875	28103	28330	28555	28780	29003	29225	29446	29666	29885	222
20	30103	30319	30535	30749	30963	31175	31386	31597	31806	32014	212
21	32222	32428	32633	32838	33041	33243	33445	33646	33845	34044	202
22	34242	34439	34635	34830	35024	35218	35410	35602	35793	35983	193
23	36172	36361	36548	36735	36921	37106	37291	37474	37657	37839	185
24	38021	38201	38381	38560	38739	38916	39093	39269	39445	39619	177
25	39794	39967	40140	40312	40483	40654	40824	40993	41162	41330	170
26	41497	41664	41830	41995	42160	42324	42488	42651	42813	42975	164
27	43136	43297	43457	43616	43775	43933	44091	44248	44404	44560	158
28	44716	44870	45025	45178	45331	45484	45636	45788	45939	46089	153
29	46239	46389	46538	46686	46834	46982	47129	47275	47421	47567	148
30	47712	47856	48000	48144	48287	48430	48572	48713	48855	48995	143
31	49136	49276	49415	49544	49693	49831	49968	50106	50242	50379	138
32	50515	50650	50785	50920	51054	51188	51321	51454	51587	51719	134
33	51851	51982	52113	52244	52374	52504	52634	52763	52891	53020	130
34	53148	53275	53402	53529	53655	53782	53907	54033	54158	54282	126
35	54406	54530	54654	54777	54900	55022	55145	55266	55388	55509	122
36	55630	55750	55870	55990	56110	56229	56348	56466	56584	56702	119
37	56820	56937	57054	57170	57287	57403	57518	57634	57749	57863	116
38	57978	58092	58206	58319	58433	58546	58658	58771	58883	58995	113
39	59106	59217	59328	59439	59549	59659	59769	59879	59988	60097	110
40	60206	60314	60422	60530	60638	60745	60852	60959	61066	61172	107
No.	0	1	2	3	4	5	6	7	8	9	Prop.

Indices of Logarithms.

Log. 4030 =3.60530
„ 403 =2.60530
„ 49.3=1.60530

Log. 4.03 = .60530
„ .403 = $\bar{1}.60530$
„ .0403 = $\bar{2}.60530$
„ .00403= $\bar{3}.60530$

No.	0	1	2	3	4	5	6	7	8	9	Prop.
41	61278	61384	61489	61595	61700	61804	61909	62013	62117	62221	104
42	62325	62428	62531	62634	62736	62838	62941	63042	63144	63245	102
43	63346	63447	63548	63648	63749	63849	63948	64048	64147	64246	99
44	64345	64443	64542	64640	64738	64836	64933	65030	65127	65224	98
45	65321	65417	65513	65609	65705	65801	65896	65991	66086	66181	96
46	66275	66370	66464	66558	66651	66745	66838	66931	67024	67117	95
47	67209	67302	67394	67486	67577	67669	67760	67851	67942	68033	92
48	68124	68214	68304	68394	68484	68574	68663	68752	68842	68931	90
49	69019	69108	69196	69284	69372	69460	69548	69635	69723	69810	88
50	69897	69983	70070	70156	70243	70329	70415	70500	70586	70671	86
51	70757	70842	70927	71011	71096	71180	71265	71349	71433	71516	84
52	71600	71683	71767	71850	71933	72015	72098	72181	72263	72345	82
53	72427	72509	72591	72672	72754	72835	72916	72997	73078	73158	81
54	73239	73319	73399	73480	73560	73639	73719	73798	73878	73957	80
55	74036	74115	74194	74272	74351	74429	74507	74585	74663	74741	78
56	74818	74896	74973	75050	75128	75204	75281	75358	75434	75511	77
57	75587	75663	75739	75815	75891	75960	76042	76117	76192	76267	75
58	76342	76417	76492	76566	76641	76715	76789	76863	76937	77011	74
59	77085	77158	77232	77305	77378	77451	77524	77597	77670	77742	73
60	77815	77887	77959	78031	78103	78175	78247	78318	78390	78461	72
61	78533	78604	78675	78746	78816	78887	78958	79028	79098	79169	71
62	79239	79309	79379	79448	79518	79588	79657	79726	79796	79865	70
63	79934	80003	80071	80140	80208	80277	80345	80414	80482	80550	69
64	80618	80685	80753	80821	80888	80956	81023	81090	81157	81224	68
65	81291	81358	81424	81491	81557	81624	81690	81756	81822	81888	67
66	81954	82020	82085	82151	82216	82282	82347	82412	82477	82542	66
67	82607	82672	82737	82801	82866	82930	82994	83058	83123	83187	64
68	83251	83314	83378	83442	83505	83569	83632	83695	83758	83822	63
69	83885	83947	84010	84073	84136	84198	84261	84323	84385	84447	63
70	84509	84571	84633	84695	84757	84819	84880	84942	85003	85064	62
No.	0	1	2	3	4	5	6	7	8	9	Prop.

Find Log. of 5065
Log. of 5060=3.70415
Prop. 86 × Diff. 5= 430

Log. required=3.704580

Find Number of Log. 3.771442
Log. of 5900=3.770850

Diff. 592÷Prop. 73=8 Diff.=592

No. required 5908

LOGARITHM OF NUMBERS FROM 0 TO 1000—Concluded.

No.	0	1	2	3	4	5	6	7	8	9	Prop.
71	85125	85187	85248	85309	85369	85430	85491	85552	85612	85673	61
72	85733	85793	86853	85913	85973	86033	86093	86153	86213	86272	60
73	86332	86391	86451	86510	86569	86628	86687	86746	86805	86864	59
74	86923	86981	87040	87098	87157	87215	87273	87332	87390	87440	58
75	87506	87564	87621	87679	87737	87794	87852	87909	87967	88024	57
76	88081	88138	88195	88252	88309	88366	88422	88479	88536	88592	57
77	88649	88705	88761	88818	88874	88930	88986	89042	89098	89153	56
78	89209	89265	89320	89376	89431	89487	89542	89597	89652	89707	55
79	89762	89817	89872	89927	89982	90036	90091	90145	90200	90254	54
80	90309	90363	90417	90471	90525	90579	90633	90687	90741	90794	54
81	90848	90902	90955	91009	91062	91115	91169	91222	91275	91328	53
82	91381	91434	91487	91540	91592	91645	91698	91750	91803	91855	53
83	91907	91960	92012	92064	92116	92168	92220	92272	92324	92376	52
84	92427	92479	92531	92582	92634	92685	92737	92788	92839	92890	51
85	92942	92993	93044	93095	93145	93196	93247	93298	93348	93399	51
86	93449	93500	93550	93601	93651	93701	93751	93802	93852	93902	50
87	93952	94001	94051	94101	94151	94200	94250	94300	94349	94398	49
88	94448	94497	94546	94596	94645	94694	94743	94792	94841	94890	49
89	94939	94987	95036	95085	95133	95182	95230	95279	95327	95376	48
90	95424	95472	95520	95568	95616	95664	95712	95760	95808	95856	48
91	95904	95951	95999	96047	96094	96142	96189	96237	96284	96331	48
92	96378	96426	96473	96520	96567	96614	96661	96708	96754	96801	47
93	96848	96895	96941	96988	97034	97081	97127	97174	97220	97266	47
94	97312	97359	97405	97451	97497	97543	97589	97635	97680	97726	46
95	97772	97818	97863	97909	97954	98000	98045	98091	98136	98181	46
96	98227	98272	98317	98362	98407	98452	98497	98542	98587	98632	45
97	98677	98721	98766	98811	98855	98900	98945	98989	99034	99078	45
98	99122	99167	99211	99255	99299	99343	99387	99431	99475	99519	44
99	99563	99607	99651	99695	99738	99782	99826	99869	99913	99956	44
No.	0	1	2	3	4	5	6	7	8	9	Prop.

To Multiply by Logarithms add the Logarithms together.
To Divide by Logarithms subtract one from the other.
To Extract the Root divide the Logarithm by the Index of the Root.
To Raise a number to any power multiply the Log. by the index.

TABLE OF NATURAL TANGENTS AND COTANGENTS.

TANGENTS.

Prop. parts to 1".	Deg.	0′	10′	20′	30′	40′	50′	Deg.	Prop. parts to 1′.
.485	0	.	.00291	.00582	.00873	.01164	.01454	89	29.
.485	1	.01745	.02036	.02327	.02619	.0291	.03201	88	29.
.486	2	.03492	.03783	.04075	.04366	.04658	.04949	87	29.
.487	3	.05241	.05532	.05824	.06116	.06408	.067	86	29.
.488	4	.06993	.07285	.07577	.0787	.08163	.08456	85	29.
.489	5	.08749	.09042	.09335	.09629	.09923	.10216	84	29.
.491	6	.1051	.10805	.11099	.11394	.11688	.11983	83	29.
.493	7	.12278	.12574	.12869	.13165	.13461	.13758	82	30.
.496	8	.14054	.14351	.14648	.14945	.15243	.1554	81	30.
.498	9	.15838	.16137	.16435	.16734	.17033	.17333	80	30.
.501	10	.17633	.17933	.18233	.18534	.18835	.19136	79	30.
.505	11	.19438	.1974	.20042	.20345	.20648	.20952	78	30.
.509	12	.21256	.2156	.21864	.2217	.22475	.22781	77	31.
.513	13	.23087	.23393	.237	.24008	.24316	.24624	76	31.
.517	14	.24933	.25242	.25552	.25862	.26172	.26483	75	31.
.522	15	.26795	.27107	.27419	.27732	.28046	.2836	74	31.
.527	16	.28675	.2899	.29305	.29621	.29938	.30255	73	32.
.533	17	.30573	.30891	.3121	.3153	.3185	.32171	72	32.
.539	18	.32492	.32814	.33136	.33459	.33783	.34108	71	32.
.546	19	.34433	.34758	.35085	.35412	.3574	.36068	70	33.
.553	20	.36397	.36727	.37057	.37388	.3772	.38053	69	33.
.560	21	.38386	.3872	.39055	.39391	.39727	.40065	68	34.
.568	22	.40403	.40741	.41081	.41421	.41763	.42105	67	34.
.576	23	.42448	.42791	.43136	.43481	.43828	.44175	66	34.
.585	24	.44523	.44872	.45222	.45573	.45924	.46277	65	35.
.595	25	.46631	.46985	.47341	.47698	.48055	.48414	64	36.
.605	26	.48773	.49134	.49495	.49858	.50222	.50587	63	36.
.616	27	.50953	.5132	.51687	.52057	.52427	.52798	62	37.
.628	28	.53171	.53545	.53914	.54296	.54673	.55051	61	38.
.64	29	.55431	.55812	.56194	.56577	.56962	.57348	60	38.
.653	30	.57735	.58123	.58513	.58904	.59297	.59691	59	39.
.667	31	.60086	.60483	.60881	.6128	.61681	.62083	58	40.
.682	32	.62487	.62892	.63299	.63707	.64117	.64528	57	41.
.697	33	.64941	.65355	.65771	.66189	.66608	.67028	56	42.
.714	34	.67451	.67875	.68301	.68728	.69157	.69588	55	43.
.731	35	.70021	.70455	.70891	.71329	.71769	.72211	54	44.
.75	36	.72654	.731	.73547	.73996	.74447	.749	53	45.
.77	37	.75355	.75812	.76272	.76733	.77196	.77661	52	46.
.792	38	.78129	.78598	.7907	.79544	.8002	.80498	51	47.
.814	39	.80978	.81461	.81946	.82434	.82923	.83415	50	49.
.838	40	.8391	.84407	.84906	.85408	.85912	.86419	49	50.
.864	41	.86929	.87441	.87955	.88472	.88992	.89515	48	52.
.892	42	.9004	.90568	.91099	.91633	.9217	.92709	47	53.
.921	43	.92552	.93797	.94345	.94896	.95451	.96008	46	55.
.953	44	.96569	.97133	.977	.9827	.98843	.9942	45	57.
.99	45	1.	1.00583	1.0117	1.01761	1.02355	1.02952	44	59.
1.02	46	1.03553	1.04158	1.04766	1.05378	1.05994	1.06613	43	61.
1.06	47	1.07237	1.07864	1.08496	1.09131	1.0977	1.10414	42	63.
1.1	48	1.11061	1.11713	1.12369	1.13029	1.13694	1.14363	41	66.
		60′	50′	40′	30′	20′	10′	Deg.	

COTANGENTS.

TABLE OF NATURAL TANGENTS AND COTANGENTS.

TANGENTS.

Prop. parts to 1″.	Deg.	0′	10′	20′	30′	40′	50′	Deg.	Prop. parts to 1′.
1.15	49	1.15037	1.15715	1.16398	1.17085	1.17777	1.18474	40	69.
1.2	50	1.19175	1.19882	1.20593	1.2131	1.22031	1.22758	39	72.
1.25	51	1.2349	1.24227	1.24969	1.25717	1.26471	1.2723	38	75.
1.31	52	1.27994	1.28764	1.29541	1.30323	1.3111	1.31904	37	78.
1.37	53	1.32704	1.33511	1.34323	1.35142	1.35968	1.368	36	82.
1.44	54	1.37638	1.38484	1.39336	1.40195	1.41061	1.41934	35	86.
1.51	55	1.42815	1.43703	1.44598	1.45501	1.46411	1.4733	34	90.
1.59	56	1.48256	1.4919	1.50133	1.51084	1.52043	1.5301	33	95.
1.68	57	1.53986	1.54972	1.55966	1.56969	1.57981	1.59002	32	100.
1.78	58	1.60033	1.61074	1.62125	1.63185	1.64256	1.65337	31	107.
1.88	59	1.66428	1.6753	1.68643	1.69766	1.70901	1.72047	30	113.
2.	60	1.73205	1.74375	1.75556	1.76749	1.77955	1.79174	29	120.
2.13	61	1.80405	1.81649	1.82906	1.84177	1.85462	1.8676	28	128.
2.27	62	1.88073	1.894	1.90741	1.92098	1.9347	1.94858	27	136.
2.44	63	1.96261	1.97681	1.99116	2.00569	2.02039	2.03526	26	146.
2.62	64	2.0503	2.06553	2.08094	2.09654	2.11233	2.12832	25	157.
2.82	65	2.14451	2.1609	2.17749	2.1943	2.21132	2.22857	24	169.
3.05	66	2.24604	2.26374	2.28167	2.29984	2.31826	2.33693	23	183.
3.31	67	2.35585	2.37504	2.39449	2.41421	2.43422	2.45451	22	199.
3.61	68	2.47509	2.49597	2.51715	2.53865	2.56046	2.58261	21	217.
3.95	69	2.60509	2.62791	2.65109	2.67462	2.69853	2.72281	20	235.
4.35	70	2.74748	2.77254	2.79802	2.82391	2.85023	2.877	19	261.
4.82	71	2.90421	2.93189	2.96004	2.98868	3.01783	3.04749	18	289.
5.36	72	3.07768	3.10842	3.13972	3.17159	3.20406	3.23714	17	322.
6.01	73	3.27085	3.30521	3.34023	3.37594	3.41236	3.44951	16	360.
6.79	74	3.48741	3.52609	3.56557	3.60588	3.64705	3.68909	15	407.
7.73	75	3.73205	3.77595	3.82083	3.86671	3.91364	3.96165	14	464.
8.9	76	4.01078	4.06107	4.11256	4.1653	4.21933	4.27471	13	534.
10.35	77	4.33148	4.38969	4.44942	4.51071	4.57363	4.63825	12	621.
12.2	78	4.70463	4.77286	4.843	4.91516	4.9894	5.06584	11	732.
14.6	79	5.14455	5.22566	5.30928	5.39552	5.48451	5.57638	10	876.
17.8	80	5.67128	5.76937	5.8708	5.97576	6.08444	6.19703	9	1068.
22.19	81	6.31375	6.43484	6.56055	6.69116	6.82694	6.96823	8	1331.
28.46	82	7.11537	7.26873	7.42871	7.59575	7.77035	7.95302	7	1708.
37.83	83	8.14435	8.34496	8.55555	8.77689	9.00983	9.2553	6	2270.
52.8	84	9.5144	9.7882	10.078	10.3854	10.7119	11.0594	5	3168.
78.8	85	11.4301	11.8262	12.2505	12.7062	13.1969	13.7267	4	4728.
130.1	86	14.3007	14.9244	15.6048	16.3499	17.1693	18.075	3	7806.
	87	19.0811	20.2056	21.4704	22.9038	24.5418	26.4316	2	
	88	28.6363	31.2416	34.3628	38.1885	42.9641	49.1039	1	
	89	57.29	68.7501	85.9398	114.589	171.885	343.774	0	
		60′	50′	40′	30′	20′	10′	Deg.	

COTANGENTS.

The preceding Table contains the Natural Tangents and Cotangents for every ten minutes of the quadrant, to the radius of 1.

The degrees in the column on the left side and the minutes at the head of the page are for Tangents, and contrariwise for Cotangents.

If the degrees are taken in the column on the left side, the minutes and tangents must be taken from the head of the page; and if they are taken from the column on the right side, the minutes and cotangents must be taken from the foot.

ILLUSTRATION.—.1974 is the tangent for 11° 10′, and the cotangent for 78° 50′.

NATURAL TANGENT AND COTANGENTS.

TO COMPUTE THE TANGENT OR COTANGENT FOR MINUTES NOT GIVEN AT THE HEAD OR FOOT OF THE COLUMNS.

Ascertain from the Table the Tangent or Cotangent of the angle for degrees, and the next less numbers of minutes given in the line opposite to the degrees. Take the correction or number for one minute from the right-hand column of Proportional Parts, and opposite to the degrees given; multiply it by the number of minutes, and add the product to the result for degrees and minutes before obtained, if the Tangent is required, and subtract it if the Cotagent is required.

EXAMPLE.—What is the tangent of $10^\circ\ 15'$?

Tangent of $10^\circ\ 10'$, per Table $= .17933$.

The correction for $1'$ over $10'$ is 30, which, multiplied by 5 $(15 - 10) = 150$, and $.17933 + 150 = .18083$, *the tangent.*

Ex. 2.—What is the cotangent of $79^\circ\ 45'$?

Cotangent of $79^\circ\ 40'$ per Table $= .18233$.

The correction for $1'$ over $40'$ is 30, which, multiplied by 5 $(15 - 10) = 150$, and $.18233 - 150 = .18083$, *the cotangent.*

TO COMPUTE THE TANGENTS OR COTANGENTS FOR SECONDS.

Ascertain from the Table the Tangent or Cotangent of the angle for degrees and minutes. Take the correction or number for one second from the left-hand column of Proportional Parts, and multiply it by the number of seconds; add the product to the result for degrees and minutes before obtained, if the Tangent is required, and subtract if the Cotangent is required.

EXAMPLE.—What is the tangent of $54^\circ\ 40'\ 40''$?

Tangent of $54^\circ\ 40'$, per Table $= 1.41061$.

The correction for $1''$ over 54° is 1.44, which, multiplied by $40'' = 58$, and $1.41061 + 58 = 1.41119$, *the tangent.*

TO COMPUTE THE TANGENT OR COTANGENT OF ANY ANGLE IN DEGREES, MINUTES, AND SECONDS.

Divide the Sine of the angle by the Cosine for the Tangent, and the Cosine by the Sine for the Cotangent.

EXAMPLE.—What is the tangent of $25^\circ\ 18'$?

The sine of this angle $= .42736$; the cosine of this angle $= .90408$.

$$\text{Then } \frac{.42736}{.90408} = .4727, \textit{ the tangent.}$$

TO COMPUTE THE NUMBER OF DEGREES, MINUTES, AND SECONDS OF A GIVEN TANGENT OR COTANGENT.

When the Tangent is given,

Proceed according to the following

EXAMPLE.—What is the tangent for 1.41119?

The next less tangent is 1.41061, *the arc for which is* 54° 40′.

The next greatest tangent is 1.41934, *the difference between which and the next less is* 1.41934 — 1.41061 = .00873.

The difference between the less tabular tangent and the one given is 1.11061 — 1.41119 = .00058.

Then 873 : 580 (58 × 10 for tangent of 10′) : : 60 : 40, which, added to 54° 40′ = 54° 40′ 40″.

When the Cotangent is given,

Proceed as by Rule, page 311, for Cosines, substituting Cotangents for Cosines.

WHATMAN'S DRAWING PAPERS—SIZES OF SHEETS.

Antiquarian	52 × 31	inches.
Double Elephant	40 × 27	"
Atlas	34 × 26	"
Colombier	34 × 23	"
Imperial	30 × 22	"
Elephant	28 × 23	"
Super-royal	27 × 19	"
Royal	23 × 19	"
Medium	22 × 17	"
Demy	20 × 15	"

D. K. CLARK, Rules, Tables, and Data.

SPECIFIC GRAVITY.

By specific gravity is meant the weight of a substance compared with the weight of water, taking equal volumes of each. A cubic foot of cast iron weighs about 7½ times as much as a cubic foot of water, but a cubic foot of cork weighs less than one-fourth as much as a cubic foot of water, and so the specific gravity of cast iron is set down as 7.5, and that of cork as 0.24.

It so happens that a cubic foot of water weighs about 1,000 ounces (exactly 997.68 ounces) and taking advantage of this, if we weigh a cubic foot of any substance by ounces, the result will express approximately the specific gravity multiplied by 1,000, because in expressing specific gravity the world has agreed always to consider the weight of the water used in comparison as 1.

The beauty and simplicity of the metric system to the mind of the student is illustrated by the fact that the weight of a cubic centimetre of any substance expressed in grammes, is the specific gravity of that substance, because in theory a cubic centimetre of water always weighs 1 gramme.

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS.

METALS.

	Specific Gravity.	Weight per cu. ft.	Cu. ft. in one ton.
Aluminum	2.6	162.	13.3
Antimony, cast, 6.66 to 6.74 .	6.7	418.	5.3
" native . . .	6.67	416.	5.3
Bismuth, cast and native .	9.74	607.	3.6
Brass, copper and zinc, cast, 7.8 to 8.4	8.1	504.	4.4
Brass, rolled	8.4	524.	4.2
Bronze, copper 8, and tin 1, Gun Metal 8.4 to 8.6 . .	8.5	529.	4.2
Copper, cast, 8.6 to 8.8 . .	8.7	542.	4.1
" rolled, 8.7 to 8.9 . .	8.8	549.	4.0
Gold, cast, pure or 24 carat .	19.258	1204.	1.86
" native, pure, 19.3 to 19.34	19.32	1205.	1.85
" " with silver, 15.6 to 19.3			
Gold, pure hammered, 19.4 to 19.6	19.5	1217.	1.84
Iron, cast, 6.9 to 7.4 . .	7.21	450.	4.8
" wrought, 7.6 to 7.9 .	7.77	485.	4.6
" large rolled bars . .	7.69	480.	4.6
" sheet		485.	4.6
Lead	11.4	712.	3.15
Mercury at 32° F. . . .	13.62	849.	2.6
" " 60° F. . . .	13.58	846.	2.6
" " 212° F. . . .	13.38	836.	2.6
Platinum, 21 to 22 . . .	21.5	1342.	1.6
" native in grains .	17.5		
Silver	10.5	655.	3.4
Steel, crucible, average . .	7.842	489.	4.5
" cast " . .	7.848	489.3	4.5
" Bessemer . . .	7.852	489.6	4.5
Speltre or Zinc, 6.8 to 7.2 .	7.00	437.5	5.1
Tin, cast, 7.2 to 7.5 . .	7.35	459.—	4.8
Type Metal	10.45	653.—	3.4

Woods.

	Specific Gravity.	Weight per cu. ft.	Cu. ft. in one ton.
Ash, perfectly dry	.752	47.—	1.748
Ash, American White, dry .	.61	38.	1.414
Birch		45.	
Boxwood, dry	1.04	64.8	
Cedar, red, green . . .		32.	
Cherry	.672	42.	1.562
Chestnut, perfectly dry . .	.66	41.	1.525
Elm " " . .	.56	35.	1.302
Ebony " " . .	1.22	76.1	
Hemlock " " . .	.40	25.—	.930
Hickory " " . .	.85	53.	1.971
Lignum Vitæ " . .	1.33	83.	
Mahogany, Spanish, dry . .	.85	53.	
" Honduras " . .	.56	35.	
Maple, dry	.79	49.	
Oak, live, dry	.95	59.3	
" white, dry	.70	44.	
" red		.32 to .45	
Pine, white, perfectly, .35 to .45	.40	25.	.930
" yellow, Northern, .48 to .62	.55	34.3	1.276
Pine, yellow, Southern, .64 to .80	.72	45.	1.674
Pine, yellow, heart of long leafed Southern, yellow, unseasoned	1.04	65.	2.418
Sycamore, perfectly dry . .	.59	37.	1.370
Spruce " " . .	.40	25.	.930
Walnut, black " " . .	.61	38.	1.414

Stones and Minerals.

Basalt, see Limestones . .	2.9	181.	
Bathstone, Oolite . . .	2.1	131.	
Calcite, transparent, 2.52 to 2.73	2.62		
Diamond, 3.44 to 3.55 . .	3.53		
Emerald	3.95		
" aqua marine . .	2.73		
Flint	2.60	162.—	13.8
Feldspar	2.60	162.	13.8
Garnet	3.60 to 4.20		

	Specific Gravity.	Weight per cu. ft.	Cu. ft in one ton.
Granite, Sienite, Gneiss	2.36 to 2.96	147.1 to 184.6	12.1
" Gray, .	2.80 to 3.06	174.6 to 190.8	11.8
Graphite	2.20	137.2	16.3
Gneiss, common . 2.62 to 2.76	2.69	168.	
" in loose piles . .		96.	
" Hornblendic . .	2.80	175.	
" " quarried in loose piles,		100.	
Gypsum, Plaster of Paris .	2.27	141.6	15.8
" in irregular lumps .		82.	
" ground loose per struck bushel, 70 lbs.		56.	
" well shaken, per struck bushel, 80 lbs.		64.	
" thoroughly shaken, per struck bushel, 90 lbs.		72.	
Greenstone, trap 2.8 to 3.2 .	3.—	187.	
" " quarried in loose piles,		107.	
Hornblende, black 3.1 to 3.4 .	3.25	203.	
Limestones and Marbles 2.4 to 2.86	2.6	164.4	13.6
Limestones and Marbles, they are frequently . . .	2.7	168.0	13.3
Lime-quick, ground, loose, per struck bushel 62 to 70 lbs.		53.	42.2
Lime-quick, ground, thoroughly shaken, per struck bush. 93¾,		75.—	29.8
Mica, 2.75 to 3.1	2.93	183.	12.2
Oolites or Roestones, 1.9 to 2.5,	2.2	137.	
Quartz, common, pure, 2.64 to 2.67	2.65	165.	13.5
Quartz, common, finely pulverized, loose . . .		90.	24.8
Quartz, finely pulverized, well shaken		105.	
Quartz, well pulverized, well packed		112.	
Quartz, quarried, loose. One measure solid makes full 1¾ broken and piled .		94.	23.8
Ruby and Sapphire, 3.95 to 3.96	3.9		

	Specific Gravity.	Weight per cu. ft.	Cu. ft in one ton
Sand, with its natural moisture and loose		.85 to .90	24.8
Sand, pure, quartz, perfectly dry	1.7	106.	
Sand, perfectly wet, voids full of water		118 to 129	17.3
Sand, at 98 lbs. per foot a struck bushel, weighs 122.5 lbs. .			
Sandstones, fit for building, dry, 2.1 to 2.73 . . .	2.41	150.—	
Sandstones, quarried and piled. One measure, solid, makes 1¾ piled . . .		86.	26.
Serpentines	2.81	175.2	12.8
Shales, red or black, 2.4 to 2.8,	2.6	162.	
" quarried in piles .		92.	24.3
Slate, 2.7 to 2.9	2.8	175.	12.8
Soapstone or Steatite, 2.65 to 2.8	2.73	170.	13.1
Sapphire and Ruby, 3.96 to 3.95	3.90		
Trap, compact, 2.8 to 3.2 .	3.—	187.	
" quarried, in piles . .		107.	20.9
Topaz	3.55		
Zircon	4.50		

General List.

	Specific Gravity.	Weight per cu. ft.	Cu. ft in gross ton.
Air, atmosphere at 60° F, Barom. 30″	.00123	.0765	
Alcohol, pure	.793	49.43	
" of commerce . .	.834	52.10	
" proof spirit . .	.916	57.2	
Alabaster, a compact plaster of Paris	2.31	144.0	
Anthracite, solid, 1.3 to 1.84, average	1.50	93.5	
Anthracite, broken, of any size, loose		52. to 56.	40. to 43
Asphaltum	1.4	87.3	25.6
Basalt, see Limestones . .	2.9	181.	
Bathstone, Oolite	2.1	131.	
Bitumen, solid, see Asphaltum,			
Brickwork, see Masonry . .			

	Specific Gravity.	Weight per cu. ft.	Cu. ft. in gross ton.
Carbonic Acid Gas, 1½ times as heavy as air . .	.00187		
Charcoal of Pines and Oaks .		15 to 30.	74.6
Chalk, air dried .	2.46 to 2.55	150 to 159	14.1 to 14.9
Clay, potters, dry, 1.8 to 2.1 .	1.9	119.	18.8
" dry, in lumps, loose .		63.	35.5
Coke, loose, of good coal .		23 to 32	
" a heaped bushel, loose, 35 to 42 lbs.			80 to 97
Coal, bituminous, 1.2 to 1.5 .	1.35		
" " broken and loose .		47 to 52	43 to 48
Cement, English Portland,	1.25 to 1.51	78 to 94	23.8 to 28.7
" " " per barrel 400 to 430 .			
Cement, U. S. Rosendale, loose		56.—	
" " " a struck bushel, 62 to 70 lbs. .			
Cork	.25	15.6	
Earth, common loam, perfectly dry, loose		72 to 80	
Earth, common loam, perfectly dry, shaken moderately .		82 to 92	
Earth, common loam, perfectly dry, rammed		90 to 100	22.4 to 24.8
Earth, common loam, slightly moist, loose		70 to 76	
Earth, common loam, more moist, loose		66 to 68	
Earth, common loam, more moist, shaken moderately .		75 to 90	
Earth, common loam, more moist, packed		90 to 100	
Earth, common loam, as a soft flowing mud		104 to 112	
Earth, common loam, as a soft mud well, pressed into a box		110 to 120	
See Sand, Mud and Gravel .			
Ether	.716	44.6	
Fat	.93	58.	
Glass, 2.5 to 3.45	2.98	186.	
" common window . .	2.52	157.	

	Specific Gravity.	Weight per cu. ft.	Cu. ft. in gross ton.
Glass, thick flooring, Melville, N. J.	2.53	158.	
Gravel, wet, fine, sharp, well pressed,	1.99	124.	18.
See Earth, Mud and Sand			
Gutta Percha	.98	61.1	
Hydrogen Gas is 14.5 times lighter than air and 16 times lighter than oxygen		.00527	
Ivory	1.82	114.	
Ice, at 32° F	.92	57.5	38.9
India Rubber	.93	58.	
Lard	.95	59.3	
Masonry, of granite or limestones, well dressed		165.	13.57
Masonry, of granite, well scabbled, mortar rubble. About 1-5 of the mass mortar		154.	14.54
Masonry, of granite rubble, well scabbled, dry		138.	16.23
Masonry, of granite rubble, roughly scabbled, mortar. About ¼ to ⅓ of the mass, mortar		150.	14.93
Masonry, of granite rubble, roughly scabbled, dry		125.	17.92
At 155 per cu. ft. — 14.45 cu. ft. in 1 ton			
Masonry, of brickwork, pressed brick, fine joints		140.	16.—
Masonry, of brickwork, medium quality		125.	17.92
Masonry, of brickwork, coarse, soft bricks		100.	22.4
Mortar, hardened, 1.4 to 1.9	1.65	103.	
Mud, dry, close		80 to 110	20.3 to 28
" wet, moderately pressed,		110 to 130	17.2 to 20.3
" wet, fluid		104 to 120	
See Earth, Sand and Gravel			
Naphtha	.848	52.9	
Nitrogen Gas is about 1-35 part lighter than air		.0744	

	Specific Gravity.	Weight per cu. ft.	cu. ft. in gross ton.
Oils, whale, olive	.92	57.3	
Oils of Turpentine	.87	54.3	
Oxygen Gas, a little more than 1-10 heavier than air .	.00136	.0846	
Petroleum	.878	54.8	40.87
Peat, dry, unpressed . .		20 to 30	
Pitch	1.15	71.7	
Plaster of Paris, see Gypsum .			
Powder, slightly shaken . .	1.—	62.3	
Rosin	1.1	68.6	32.65
Salt, coarse, per struck bushel, Syracuse, N.Y., 56 lbs. .		45.—	49.77
Salt, coarse, per struck bushel, Turks Island, 76 to 80 .		62.	
Salt, coarse, per struck bushel, St. Barts, 84 to 90 .		70.—	32.—
Salt, coarse, per struck bushel, well dried, W. I., 90 to 96,		74.	
Salt, coarse, per struck bushel, Liverpool, 50 to 55 . .		42.	
Salt, fine, Liverpool, for table use, 60 to 62 . . .		49.	
Sand		90 to 106	
Snow, fresh fallen . . .		5 to 12	
" moistened and compacted by rain		15 to 50	
Sulphur	2.	125.	
Tallow	.94	58.6	
Tar	1.—	62.4	
* Water, pure rain, or distilled, at 32° F. Barom. 30″ .		62.416	
60° F. " " .	1.—	62.366	35.918
80° F. " " .		62.217	
Water, sea, 1.026 to 1.030 .	1.028	64.08	34.96
Wax, bees	.97	60.5	
Wines, .993 to 1.04 . .	.998	62.3	

* The weights of a cu. ft. of water here given, are from Hydraulics, page 14, by Hamilton Smith, Jr., member Amer. Soc. C. E., who computed them from Rosetti's deductions from his own and others experiments. Mr. Smith says, that these experiments of Rosetti, Kopp and others, embody the most accurate determinations thus far made.

MATERIALS OF ENGINEERING.

Stones, Limes and Cements.

These notes are taken chiefly from Prof. R. H. Thurston's elaborate treatise on The Materials of Engineering.

The nomenclature of stone masonry has been revised by a committee of the American Society of Civil Engineers, and the specifications of the engineer are recommended to be made in accordance with their report and as below.

Stones are classed thus:

In practice one class merges into the next.

I. Unsquared Stones or Rubble. — This class includes stones used as they come from the quarry, without other preparation than the removal of sharp angles and projections.

II. Squared Stones.— Stones roughly squared and dressed on beds and joints. Where the dressing on the joints is such that the average distance between the surfaces of adjoining stones is one-half inch or more, they properly belong to this class.

Sub-divisions of class II.

(a) Quarry-faced stones, which are left untouched as they come from the quarry.

(b) Pitch-faced stones have the arris clearly defined by a line, beyond which the rock is cut away, so as to produce edges approximately true.

(c) Drafted stones have the face surrounded by a chisel draft, the space inside the draft being left rough. In ordering stones the specifications should state the width of bed and end joints, and how far the surface of the face may project beyond the plane of the edge. In practice this projection varies from 1 to 6 inches.

III. Cut Stones. — This class includes all squared stones with smoothly dressed beds and joints. The usual methods of dressing stones are called Rough Pointed, Fine Pointed, Crandalled, Axed or Pean Hammered, Patent Hammered, Tooth Axed, Bush Hammered, Rubbed and Diamond Panels.

Stone Masonry may be:

(1) Rubble Masonry, composed of unsquared stones, and it may be coursed or uncoursed, that is levelled off at specified heights, or laid in irregular courses.

(2) Squared Stone Masonry, which may be of quarry-faced or pitch-faced stones; if laid in regular courses it is Range Work; laid in courses that are not continuous throughout the length of the wall it is Broken Range Work; and if not laid in courses, it is Random Work, and this is generally the method adopted.

(3) Ashlar Masonry, made of cut stone. When the courses are continuous, but broken by the introduction of

smaller stones, it is called Broken Ashlar. If the stones are less than one foot in height the term Small Ashlar is proper. The term Rough Ashlar is sometimes given to squared stone masonry when laid as Range Work; but it is better to call such masonry "Squared Range Work."

MEASUREMENT OF MASONRY.

Stone work is measured by taking openings less than 3 feet wide as solid wall, and adding 18 inches for each jamb. Arches are usually taken as solid from the springing line; corners are measured twice, and pillars are measured by the area of three sides multiplied by the fourth. Foundation and dimension stones are measured by cubic measure; water tables and base courses in lineal feet, and sills and lintels in superficial feet.

BRICKWORK. — Broken and soft bricks should be rejected and each brick should be wetted and cleaned before laying it in place. The joints should be as thin as $\frac{1}{4}$ or $\frac{3}{16}$ of an inch.

About one-fifth as much mortar as brick is generally used.

The "English Bond" in which entire courses of stretchers and headers are laid at regular intervals as the wall rises, is considered strongest when laid one course of headers to each two courses of stretchers; the strength is very nearly the same length-wise and cross-wise. "Flemish Bond" is laid header and stretcher alternating in each course. It is easier to retain regularity in breaking joints in this bond, but it lacks strength and is not as neat in appearance as English bond.

Brick work is measured by the thousand bricks. With average sizes and good work the following are the number of bricks laid by the superficial foot.

4	inch	wall	7	bricks	to	square	foot.
9	"	"	14	"	"	"	"
13	"	"	21	"	"	"	"
18	"	"	28	"	"	"	"
22	"	"	35	"	"	"	"

Corners are measured twice; small openings are taken as solid work; arches are measured as solid from the springing line; and pillars are measured on the face.

Masonry will carry safely from 2 to 10 tons per sq. ft. according to quality; and carefully built masses of cut

and dressed granite may carry four times the higher figure. In D. K. Clark's rules, tables, and data, the crushing strength of brick work in cement not hard, is given as 0.232 tons per square inch, but the strength of brick walls decreases as the height increases, or in other words the chance that the wall may be destroyed by "buckling" under pressure comes into action.

Masonry in damp situations is always laid in hydraulic mortar or cement, and the lower courses of walls and foundations are usually carried below the frost line. The soil should be carefully drained. Where new masonry abuts upon old work, there is always danger of cracking by the settling of the new work; but every precaution should be taken to secure a good bond between the two portions, and to make the joints of the new work thin, and of cementing material of such consistency as will prevent excessive shrinkage.

As to the cost of masonry, the items, labor in particular, are subject to such variation that we can only give sample estimates as guides to the method to be followed.

(THURSTON.)

COST OF ASHLAR MASONRY.

Laborer $1.50 per day. Mason $2.25.

Quarrying 1⅓ cubic yards . .	$3.00	
Dressing 16 sq. ft. face @ 25 cts. .	4.00	
Dressing 48 sq. ft, joint @ 12½ cts.	6.00	
Cost of stone per yard		$13.00
Haulage, variable, say . . .	$1.50	
Mortar	.50	
Laying one cubic yard and incidentals	1.50	
Cost of placing		$3.50
Contractor's profit, 15 per cent . . .		2.50
Total cost per cu. yd.		$19.00

(TRAUTWINE.)

ASHLAR FACING MASONRY.

Laborer $2.00 per day of 8 hours. Mason $3.50.
Two stones per cu. yd.

Getting out stone from quarry by blasting, allowing ¼ for waste in dressing; 1⅓ cu. yds. @ $3.00	$4.00

Dressing, 14 sq. ft: of face @ 35 cts.	4.90
Dressing, 52 sq. ft. of beds and joints @ 18 cts.	9.36
Neat cost of dressed stone at quarry	18.26
Hauling, say 1 mile; loading and unloading	1.20
Mortar	.40
Laying, including scaffold, hoist, supt.	2.00
Neat cost	21.86
Profit to contractor, 15 per cent	3.28
(TRAUTWINE.)	$25.14

LARGE, SCABBLED, GRANITE RUBBLE.

Labor $1 per day.	
Getting out the stone from quarry by blasting, allowing 1/8 for waste in scabbling; 1 1/7 yards @ $3.00	$3.43
Hauling, 1 mile, loading and unloading	1.20
Mortar (2 cu. ft. or 1.6 struck bushels of quicklime, either lump or ground; and 10 cu. ft. or 8 struck bushels of sand and gravel; and mixing)	1.50
Scabbling; laying, including scaffold, hoist, etc.	2.50
Neat cost	8.63
Profit to contractor, 15 per cent	1.30
Total cost per cu. yard.	9.93

LIMES.

(THURSTON.)

As a building material, lime is of three principal kinds; common or air lime, hydraulic lime, and hydraulic or water cement.

Common lime, also called pure, rich, or fat lime is produced by calcining limestone which is nearly pure carbonate of lime, and thus expelling its carbonic acid.

Common lime slakes by greedily absorbing moisture, becoming converted into a dry hydrate, if water is not used to excess. Made into a paste with water it hardens slowly in the air, but not at all under water.

HYDRAULIC LIMES are made from stones containing 18 to 30 per cent. of silicate of alumina, of carbonate of magnesia, or a mixture of both. They slake more slowly than air lime, and the paste hardens very slowly under water or in wet localities.

HYDRAULIC CEMENTS are made by calcining limestones containing from 30 to 60 per cent. of clay. They do not slake and their pastes harden with rapidity under water. They are therefore of greatest use in building foundations. Where the proportion of silicate of alumina is greater than 60 per cent., the material is called puzzolana, and it requires the addition of fat lime to render it useful. Natural puzzolana is of volcanic origin. Brick-dust has a similar power of rendering fat limes hydraulic, as has also trass, terras, or blue trap-rock.

There are stones which are naturally limes or cements.

English Portland cement is made by grinding together chalk and clay, and is the strongest and most expensive cement in the market.

Roman cement is made from nodules of limestone containing clay and iron. It sets more quickly but is less hard than the English Portland.

MORTARS are mixtures of some kind of lime and sand with water.

Common Mortar is made with fat lime and sand, usually 1 part to 5 by volume.

Hydraulic Mortar is made with some hydraulic lime and sand. It hardens under water slowly, but if of good quality makes a firm, binding material.

Hydraulic Cement is a mortar made with a lime whose hydraulic qualities are very pronounced. Some of these hydraulic cements set in a few minutes after mixture.

The sand used in mixing mortars should be free from clay and perfectly clean. It should be sharp and rather coarse. River sand is usually found to be better than sea sand, as it is free from salt, and is less liable to be found water-worn.

There is a wide range to the proportions in which sand and cement are mixed. A mixture of equal parts is strong and serviceable, and even better than much of ordinary work requires.

Cement Concrete or Béton is a mixture of cement, sand, or gravel and stones with water, and has been used in the following proportions on the works named with excellent results:

Croton Aqueduct, New York:

New York cement	1 part by volume
Sand	3 " " "
Broken stone to pass through 1½ ring	3 " " "

Cherbourg Breakwater, France:

Portland cement	1 part
Sand	3 parts

BETON-COIGNET as made by the French engineer, M. F. Coignet, and which attracted much attention at the Paris Exposition of 1867 is composed of

Lime	4 parts
Hydraulic cement	1 to 2 parts
Sand	20 parts

The ingredients are first thoroughly inter-mixed dry, by hand, and again in a mill, moistening them slightly with clean water. Moulds are then filled with the mixture, and it is compacted by ramming or hammering. (See Gen. Q. A. Gilmore on Béton-Coignet).

STRENGTH OF MORTARS AND CEMENTS.

Mortar has a tenacity of from 6 to 34 pounds per square inch, when six months old. The average, according to Gen. Totten, U. S. A., is about 15 pounds per square inch.

The resistance to crushing , a year and one-half after setting, is given by Rondelet as from 440 to 580 pounds per square inch when simply laid in place, and from 600 to 800 pounds when well rammed.

A source of valuable information upon cement and cement mortars is to be found in a paper by Mr. Elliot C. Clarke, published in Trans. Am. Soc. C. E., April, 1885, from which the following table is taken.

TENSILE STRENGTH OF CEMENT MORTARS.

(ROSENDALE).

	1 Day.	1 Wk.	1 Mo.	6 Mo.	1 Yr.
NEAT.	71	92	145	282	290
CEMENT 1, SAND 1.		56	116	180	236
CEMENT 1, SAND 1-5.		41	90	135	210
CEMENT 1, SAND 2.		22	49	105	169
CEMENT 1, SAND 3.		12	25	65	121
CEMENT 1, SAND 5.			10	36	80

(PORTLAND).

	1 Day.	1 Wk.	1 Mo.	6 Mo.	1 Yr.
NEAT.	102	303	412	468	494
CEMENT 1, SAND 1.		106	225	347	387
CEMENT 1, SAND 1-5.					
CEMENT 1, SAND 2.		126	163	279	323
CEMENT 1, SAND 3.		95	130	198	257
CEMENT 1, SAND 5.		55	78	116	145

The average crushing strength of neat cements after six days in water is given by Trautwine for common American cements as from 250 to 450 pounds per square inch, and for the best Portlands as from 1,400 to 2,400. Gypsum or plaster of Paris is said to have a tenacity of 70 pounds per square inch.

TIMBER.

(PROF. R. H. THURSTON.)

Timber is measured when bought in market, either by the cubic foot or by *board measure*. The unit of the latter is the square foot of inch in thickness, and is denoted by the abbreviation B. M.

Sawed or hewed timber is often measured by the cubic foot.

Round timber is measured by multiplying the length by the square of one-fourth its mean girth to obtain the cubic contents. (Ordnance Manual). If L = length in feet, and C the mean circumference of the log, i. e. the half sum of the girth at the ends, also measured in feet, the volume in cubic feet is given by the expression

$$V. = L \frac{C^2}{4\pi} = \frac{L\,C^2}{13}$$

When the length is in feet and the girth in inches, divide the above result by 144 to obtain the answer in cubic feet.

STRENGTH OF TIMBER.

The most extended and accurate experiments upon the woods were made by M. M. Chevandier and Wertheim, on timber grown in the department of Vosges, France.

Their conclusions were substantially as follows:

Age affects very slightly the density of timber. Age and exposure have a marked influence on cohesion. Age diminishes the cœfficient of elasticity after the tree has passed maturity. The nature of the soil, and the locality in which the tree is grown, effect this cœfficient.

Trees grown on dry soils in northern, north-eastern, and north-western exposures, furnish timber which has the highest cœfficient. Muddy or wet soils with southern exposure, give the lowest. The season in which the tree is cut has no apparent effect upon the cœfficient. In fir, the thinner the annual layers, the greater the cœfficient of elasticity. In other woods no difference was detected arising from this cause.

Timber has no defined limit of elasticity. One is taken by some writers, assuming as a limit in extension that point at which the set becomes $\frac{1}{20000}$ of the original length. It may be taken for purposes of estimation at one-third or one-fourth of the breaking weight. THE CŒFFICIENT OF ELASTICITY represents the number of pounds per square inch required to elongate or compress a bar one inch for each inch in length of the piece experimented upon, and the following values are given by various experimenters.

COEFFICIENTS OF ELASTICITY

	Lbs. on Square Inch.
Ash	1,600.000
Box	1,800.000
Chestnut, dry	1,250.000
Elm	1,500.000
Fir, Baltic	1,800.000
Fir, New England	1,200.000
Larch	1,400.000
Lignum Vitæ	1,000.000
Mahogany	1,400.000
Oak, English	1,700.000
Pine, Pitch	1,900.000
" Red	1,800.000
" Yellow	1,600.000
" White	1,000.000
Teak, Indian	2,100.000
Willow	1,400.000

TENSILE STRENGTH.

The Modulus of *Strength* or of *Tenacity* for any material is the amount of tensile force required to pull apart a bar having a cross sectional area at the point of fracture of one square inch.

Let K = the section of the bar.
T = modulus of tenacity, and
P = the force required to pull it asunder
Then

$$P = TK \qquad K = \frac{P}{T} \qquad T = \frac{P}{K}$$

The following table gives values for T collated by Prof. Thurston from different authorities, the pull being always with the grain. The maximum figures are for mature heart wood, well seasoned and well preserved.

MODULI OF TENACITY

OR

Coefficients of Tensile Resistance.

	Lbs. per Square Inch.
Ash	10,000 to 15,000
Birch, black	7,000 " 10,000
Beech	8,000 " 12,000
Box	10,000 " 15,000
California Spruce	12,000 " 14,000
Cedar, Bermuda	4,000 " 7,500
" Guadaloupe	5,000 " 9,500
Chestnut	7,000 " 10,500
" Horse	8,000 " 12,000
Cypress	4,000 " 6,000
Elm	8,000 " 13,000
Fir (New England Spruce)	5,000 " 10,000
" Riga	5,000 " 12,500
Greenheart	6,000 " 9,000
Holly	10,000 " 15,000
Hickory, American	10,000 " 14,000
Lancewood	8,000 " 15,000
Larch	6,000 " 10,000
Lignum Vitae	10,000 " 12,000
Locust	10,000 " 15,000
Mahogany, Honduras	5,000 " 8,000
" best Spanish	8,000 " 15,000
Maple	8,000 " 10,000
Oak, American, Live	10,000
" " White	10,000
" English	9,000
" best English	12,000
Oregon Pine	9,000 " 14,000
Pear	7,000 " 10,000
Pine Pitch	8,000 " 10,000
" Red	5,000 " 8,000
" White	3,000 " 7,500
" Yellow	5,000 " 12,000
Plum	7,000 " 10,000
Poplar	7,000
Spruce	5,000 to 10,000
Teak	10,000 " 15,000
Walnut, Black	8,000
Willow	10,000

THE RESISTANCE TO CRUSHING FORCE is, with timber largely dependent also upon the conditions of its growth, seasoning and preservation; and upon the part of the tree from which it is obtained, as well as upon the form and proportion of the specimen. When the pieces tested are blocks having a height that is not very much greater than their diameter or least thickness, wood yields to compressive force by simple crushing. Where long columns are acted upon, they yield by bending and cross breaking. Pillars of intermediate height give way by combined crushing and cross breaking. Where true crushing occurs, it is assumed that the resistance is the same as that to extension, within the limit of elasticity, although this is known to be not strictly true. This resistance also varies as the area of cross section.

Let P = the crushing force

K = the area of cross section

C = the crushing stress for a unit of section,

and we shall have P = C K in which C = the *Modulus* or *Coefficient* of *Crushing Resistance*, and its value is found to be approximately constant where the length of the piece does not exceed ten times its least dimensions.

The figures in the following table are deduced from experiments upon pieces one inch in diameter and two inches long. Hogkinson found the compressive strength of wet wood to be frequently less than half that of dry.

MODULI OF CRUSHING STRENGTH

OR

COEFFICIENTS OF RESISTANCE TO CRUSHING.

	Lbs. per Square inch.
Alder	6,000 to 7,000
Ash	4,600 " 8,000
Beech	8,000 " 9,000
Birch	6,000 " 10,000
" English	5,000 " 6,500
Box	8,000 " 10,000
Cedar	4,000 " 6,500
Cherry	5,000 " 6,500
Chestnut	4,000 " 4,8000
Elm	8,000 " 10,000
Greenheart	10,000 " 14,000
Hickory	8,000 " 9,800
Larch	3,000 to 5,500
Locust	7,500 " 9,500
Lignum Vitæ	8,000 " 9,600
Maple	5,000 " 6,000

		Lbs. per Square Inch.
Mahogany, Spanish	. . . .	7,000 to 8,000
Oak, English	. . . . . .	6,500 " 10,000
" Live	. . . . . .	8,000 " 10,000
" White	. . . . . .	5,500 " 8,000
Pear	. . . .	. . 7,500
Pine, Red	. . . . . .	6,000 to 7,500
" White	. . . . . .	3,000 " 6,000
" Yellow	. . . . . .	6,500 " 10,000
Spruce	. . . .	4,500 " 6,000
Teak	. . . .	6,000 " 10,000
Walnut, Black.	. . . . .	5,600 " 7,000
" White	. . . .	7,500 " 9,000
Willow	. . . .	3,000 " 6,000

Rankine's modification of Gordon's formula for the crushing weight of a timber column is

$$P = \frac{f\,s}{1 + \frac{l^2}{a\,d^2}}$$

In which s is the sectional area in square inches, a and f constants, and l and d the length and diameter in inches. He gives for the value of a and f for timber, 188 and 7200 respectively.

The load on columns should not exceed ⅓ or ½ the crushing load.

For long pillars above thirty diameters long, Tredgold gives

$$W = A\frac{d^4}{L^2} \text{ for square pillars.}$$

$$W = A\frac{b\,t^3}{L^2} \text{ for rectangular " }$$

$$W = A\frac{d^4}{1.7\,L^2} \text{ for cylindrical " }$$

in which W = safe load in pounds
b, t and d = the breadth, thickness or diameter in inches
L = the length in feet
A = 1500 for beech, chestnut, elm and white pine; 2000 for ash and mahogany; 2500 for teak and Dantzic oak, and 2200 for red pine.

FORMULAS FOR CROSS-BREAKING in which R is a constant to be found in the table, l = length, b and d the breadth and depth of the beam in question.

W represents a distributed load

P represents a load applied at a single point.

Beam supported at both ends and loaded in middle

$$P = \frac{2 R b d^2}{3 l}$$

Same beam uniformly loaded.

$$W = \frac{4 R b d^2}{3 l}$$

MODULI OF RUPTURE OF WOODS.

VALUES OF R.

Ash . . .	12,000	Lignum Vitæ .	12,000
Beech . .	9,000	Locust . .	12,000
Birch, American	9,500	Mahogany, Spanish	8,000
Box . . .	8,500	" Honduras	10,000
Cedar, West Indian	8,000	Maple . .	8,000
" United States	8,000	Oak, Canadian .	10,000
Chestnut . .	7,000	" English .	10,000
Ebony, West Indian	15,000	" European	10,000
Elm . .	8,000	" Live .	12,000
Fir, N. E. .	7,000	" White .	11,000
" Riga .	7,000	Pine, Pitch .	8,000
" Norway .	7,000	" Red .	8,000
" Amer. Spruce	7,000	" Yellow .	7,000
Greenheart .	10,000	Teak . .	15,000
Lancewood .	15,000	Walnut . .	12,000
Larch, European	8,000	Willow . .	7,000
" American	10,000		

The subject of the transverse strength of beams is too broad a one to be adequately presented in a compilation like this, and we give only one simple formula with a table, referring the reader to Trautwine's Engineer's Pocket Book, to Prof. R. H. Thurston's Materials of Engineering, Part 1, and to D. K. Clark's Rules, Tables and Data for additional tables and data.

Trautwine gives for any beam

$$\text{Centre-breaking load in lbs.} = \frac{\text{Breadth (ins.)} \times \text{Square of depth (ins.)}}{\text{clear span in feet} \times \text{Constant.}}$$

CONSTANTS FOR FOREGOING FORMULA.

Ash, English	650	Larch	400
" Amer. White	650	Mahogany	750
" Swamp	400	Mangrove, White	650
" Black	600	" Black	550
Arbor Vitæ, Amer.	250	Maple, Black	750
Balsam, Canada	350	" Soft	750
Beech, Amer.	850	Oak, English	550
Birch, Amer. Black	550	" Amer. White	600
" " Yellow	850	" " Red	850
Cedar, Bermuda	400	" " Live	600
" Guadaloupe	600	Pine, Amer. White	450
" Amer. White or		" " Yellow	500
" Arbor Vitæ	250	" " Pitch	550
Chestnut	450	" " Georgia	850
Elm, Amer. White	650	Poplar	550
" Rock, Canada	800	Poon	700
Hemlock	500	Spruce	450
Hickory, Amer.	800	" Black	550
Iron Wood, Canada	600	Sycamore	500
Locust	700	Tamarack	400
Lignum Vitæ	650	Teak	750
Walnut	550	Willow	350

THE METALS.

TAKEN FROM PART II OF PROF. THURSTON'S MATERIALS OF ENGINEERING.

The Ancients, at the beginning and just before the Christian Era were familiar with but seven metals.

In still earlier days and before the most advanced of the human race had fairly emerged from barbarism, the only materials used in the rude constructions of those times were wood and stone. Geologists say that mankind has passed through ages of stone, of bronze and of iron, and may be considered as having just entered upon an age of steel.

The writer of Genesis says that Adam's great grandson, Tubal Cain, was an artificer in brass and iron, and the discovery of implements of metal among the ruins of the ancient cities of Asia and Africa, and in the copper mines and other localities of North America, indicate that some knowledge of metallurgy was acquired many centuries before our era. It is probably quite impossible to ascertain when, by whom, or how the first steps were taken in the progress of metallurgy.

Ancient writers are quite as ignorant on this subject as are the metallurgists of the present day.

The profane historians invariably either attribute the discovery of the useful metals to their gods, or deified those men to whom they supposed themselves indebted for the discovery or improvement of the metals and of the processes of their manufacture.

It is probable that copper may have been the first metal worked by these early metallurgists, and that tin was next discovered and used to harden the copper, as is done at the present time. In the manufacture of bronze the ancients became very skillful, probably long before the discovery and use of iron. The bronze implements discovered on both continents have sometimes nearly the hardness and sharpness of our steel tools.

The useful metals, so called, are not found "native," that is uncombined with other substances, with the exception of copper and bismuth. Copper is mined, in an uncombined state, in large quantities in the great metal bearing region of Lake Superior; and elsewhere it is found combined with sulphur.

Iron is found in every quarter of the globe, combined with oxygen, or not unfrequently with sulphur. The other useful metals all exist in combination with one or the other of these two non-metallic substances.

The relative tenacities of the metals are given approximately in the table below, lead being taken as the standard.

Lead .	1.0	Cast Iron .	7 to 12
Tin .	1.3	Wrought Iron .	20 to 40
Zinc .	2.0	Steel . .	40 to 100
Worked Copper .	12 to 20		

CAST METAL is usually weaker than the same metal, after having passed through the rolls or under the hammer; those which can be drawn into wire are still more considerably strengthened by that process. Metals are stronger at ordinary temperatures than when highly heated, and "annealing" is usually found to reduce their strength, although frequently increasing their ductility.

"Hardening" as in steel, usually produces the contrary effect.

The presence of impurities and the formation of alloys produce changes of strength, sometimes increasing, sometimes diminishing it.

Thus the addition of carbon to pure iron (producing some form of steel) increases the strength up to a limit which being passed (cast iron being formed) a diminution of strength takes place. Alloying iron with other metals generally reduces its strength; and union with sulphur or with phosphorus impairs it very seriously under some circumstances.

HARDNESS varies in the metals as considerably as their tenacity, and, like the latter quality, is greatly influenced in the same metal by very slight changes, either physical or chemical.

Thus wrought iron is hardened by cold hammering and softened by annealing. Steel has its hardness wonderfully affected by the process of tempering.

The addition of scarcely more than a trace of impurity often produces a marked change in the degree of hardness of other metals.

THE POWERS OF CONDUCTION for heat and electricity seem to have very similar relative values.

Conductivity is reduced by increase of temperature and by presence of impurities.

RELATIVE CONDUCTIVITIES OF METALS.

Gold	1,000	Zinc	360
Silver	973	Tin	304
Copper	878	Lead	180
Iron	374	Marble	25

Gold has been drawn until the wire measured but $\frac{1}{5000}$ inch in diameter, and silver and platinum are nearly as ductile. Iron and copper are the most ductile of the common metals. Gold is the most malleable of all metals and has been beaten into sheets of which it would require 300,000 to make up a thickness of one inch. Wrought iron of good quality, and the softer grades of steel are very malleable; the former has been rolled to less than $\frac{1}{1000}$ of an inch. Cast iron and the hard steels are neither malleable nor ductile.

The low temperatures of fusion of tin, lead, bismuth and antimony allow of their being readily applied as solders, either alloyed or separately.

TEMPERATURE OF FUSION OF METALS.

	Fahr.	*Cent.*
Mercury	— 39°	— 39°
Ice	+ 32	+ 0
Tin	420	216
Bismuth	490	254
Lead	630	332
Zinc	700	371
Silver	1280	693
Brass	1870	1021
Copper	2550	1118
Cast Iron	2750	1510
Wrought Iron	4000 (?)	2210 (?)

The temperatures of fusion of pure iron or of wrought irons are very high, and are not precisely known, no means of accurate measurement having yet been applied to their determination

METALS EXPAND BY HEAT, and the amount of linear expansion of metalic bars may be computed by the following formula for the Fahrenheit scale.

$$L_1 = \frac{L\left(1 + \frac{a\,t_1}{180}\right)}{1 + \frac{a\,t}{180}}$$

in which L_1 is the length of a bar at any temperature t^1, knowing its length L at any other temperature t, and a is a cœfficient to be obtained from the following table.

COEFFICIENTS OF EXPANSION OF METALS FROM 32° TO 212° F.

Glass	0.000,861,30
Platinum	0.000,884,20
Steel, soft	0.001,078,80
Iron, cast	0.001,125,00
Iron, wrought	0.001,220,40
Steel, hardened	0.001,239,50
Copper	0.001,718,20
Bronze	0.001,816,70
Brass	0.001,878,20
Tin	0.002,173,00
Lead	0.002,857,50
Zinc	0.002,941,70

IRON.

Wrought or malleable iron has been known from a period which ante-dates history, and by several nations.

A wedge of iron has been found in the Great Pyramid; hence it was known in the time of Moses 1500 B. C., and in the time of Cheops 3500 B. C., or still further back in the time of Menes 4400 B. C.

Iron occurs in large deposits in the form of oxide, and constitutes an ingredient of nearly all rocks, soils and natural waters.

In the arts, iron occurs in three forms, as wrought iron, cast iron and steel. Wrought iron is nearly pure and highly malleable, ductile and weldable, its specific gravity is 7.5 and it fuses at 1800° C. or 3240° F.

Cast or pig iron is the direct opposite of wrought iron; it is neither malleable, ductile or weldable. It is easily fused, and is therefore always cast in moulds. Its specific gravity varies from 6.9 to 7.7 and it fuses at about 1700° C. or 2700° F.

Steel is intermediate between wrought and cast iron; it is a compound of iron with a small per cent. of carbon, from ¼ to 2 per cent. With the minimum of carbon it is hardly different from wrought iron, and with the maximum it nearly approaches cast iron, in that it is rigid and brittle. Its fusing point is intermediate between cast and wrought iron.

In this connection we quote, by permission, as follows, from *Founding of Metals*, by EDWARD KIRKE.

The principal source from which we obtain our supply of iron is from the oxides and carbonates of iron or iron ores. These ores are known by different names derived from their different chemical constituents, and from the different localities from which they are obtained; as the red hematite, the brown hematite, the black band, the spar ores, the magnetic ore, the iron pyrites, the Lake Superior ore, the bog ores, the Iron mountain ore, etc. All these ores contain more or less iron, locked up with oxygen in an apparently useless stone, and some of them are very rich in iron. The iron mountain ore, which is found in the State of Missouri, is said to contain ninety per cent. of iron, and is the richest iron ore in the world. To obtain our supply of iron from these ores, we have only to separate the iron from its combination with the non-metalic part of the ores. This is done by roasting and smelting the ores in blast-furnaces. These furnaces are of different sizes, and are called one-eighth, one-fourth, one-half and full stacks; they are also divided into different grades, from certain obvious peculiarities in their construction and mode of working, and fuel used, — as the cold-blast, the hot-blast, the charcoal, the coke, or the anthracite furnaces. From these peculiarities of the furnaces the iron produced receives their different names, — as the cold-blast, and hot-blast, charcoal irons, the coke iron, and the anthracite iron. The cold-blast furnace is a furnace that is blown with a cold blast, or cold air. This class of furnaces always use charcoal fuel, and they produce the best class of iron for

machinery or any heavy work that requires great strength, such as rollers for rolling-mills, cannon, shafts and cranks for machinery, etc. This class of iron, although it runs soft in any heavy casting, will generally run hard in light castings; and it is never used in stove foundries, or in any foundry where light work is made. The cold-blast iron is the best iron for chilling, and is used in the manufacture of car wheels, crusher-jaws, and any castings that require a hard chilled surface. The hot-blast charcoal furnace is a furnace that uses charcoal as a fuel, and is blown by a hot blast. This furnace has an oven, filled with coils of pipe which are heated to a redness. The cold blast is forced through these, pipes and then into the furnace; and when it enters the furnace it is heated to redness, and is termed hot-blast; and the products of this class of furnaces are termed hot-blast charcoal iron. This class of iron is the best iron that can be procured for general foundry purposes; for it may have both hardness and softness, and it has great strength, but it has not the chilling properties of the cold-blast charcoal iron. This class of iron is extensively manfactured in the south-eastern part of Ohio, along the Ohio river, in what is known as the Hanging-rock iron region; and the iron produced is termed Hanging-rock charcoal iron. The furnaces in this region are all small furnaces; in fact, all charcoal furnaces are small, none of them being over one-eighth or one-fourth stacks. The Hanging-rock irons are principally used for foundry purposes; and in the foundries through the southern parts of Ohio, Indiana and Kentucky there is very little iron used but the Hanging-rock irons. The coke furnaces are the furnaces that use coke as a fuel. All coke furnaces are hot-blast furnaces; this class of furnaces is principally located through western Pennsylvania and along the Ohio river, and through the western States. The products of these furnaces are termed coke iron. This iron is sometimes used in foundries; but the principal part of it is used in rolling-mills in making wrought irons. The coke furnaces are the largest furnaces in this country. The Lucy furnace and the Isabell furnace, at Pittsburg, are twenty feet in diameter on the inside; these furnaces have each produced over a hundred tons of pig iron every twenty-four hours. There is a very large coke furnace at Irington, on the Ohio river; that

was put in blast about ten years ago; this furnace is said to be the largest and best built furnace in the world; it was built by the iron men of the Hanging-rock region. A man was sent all over this country and Europe to get all the modern improvements for it before its construction, and it has all the modern improvements combined, and is said to be perfect.

The anthracite furnaces are the furnaces that use anthracite coal as a fuel. All this class of furnaces are hot-blast furnaces, and the product is termed an anthracite iron. This class of iron is extensively used in foundries, and is a good iron for stove plate and all kinds of light castings. The anthracite furnaces are principally located through the eastern part of Pennsylvania, and in New York, New Jersey and Maryland, and are generally small furnaces.

To smelt iron from its ores, in the blast furnace, the ores, fuel and limestone are put into the furnace together in layers or charges; the fuel is to create heat and smelt the irons from the ores; the ores are to produce the iron, and the limestone is to act as a flux and impart igneous fluidity to the non-metallic residue of the ores and fuel, and carry it out of the furnace in the shape of slag or cinder. Practice has demonstrated the fact that, by mixing two or more ores in the furnace, the impurities in one ore may be made to impart igneous fluidity to the non-metallic residue of the other, and furnacemen have adopted the theory of using two or more ores, each having different chemical constituents, and in so doing, less limestone is required as a flux in the furnace. As the iron is smelted from its ores, it drops into the hearth or bottom of the furnace, and is drawn off in a channel cut in the sand in the floor of the casting-house, and from this main channel it is run into molds or pigs. As the iron chills in the mold it is call pig iron or cast iron, and the iron remaining in the large channel is called the sow pig—hence the term pig iron.

There are a great many varieties of iron; the principal ones are cast iron, wrought iron and steel. The difference between these irons is caused by the different proportions of carbon and other impurities which they contain. Cast iron or pig iron is the form of the iron as it comes from the blast-furnace; it is brittle and cannot be welded, and it is neither malleable nor ductile. This

iron expands at the moment of solidification, so as to copy exactly every line of the mold into which it is poured, and it contracts on cooling. These qualities fit it for casting into sand or other molds; and these castings may be made so soft as to be easily filed or turned, or they may be made so hard, by chilling in an iron mold, that no tool will cut them. Cast iron contains from two to five or six per cent. of carbon, and as the carbon increases or diminishes, the iron becomes harder or softer, and is termed a No. 1, 2 or 3 iron. That which contains the most carbon is the softest iron, but it is not always the strongest iron. As the carbon decreases, the cast iron grows harder, and after it gets past a certain point it grows weaker. Cast iron is often combined with other substances as well as carbon; it has a great affinity for sulphur, phosphorus, silica, and other impurities; it is also often alloyed with manganese, forming speigeleisen iron; with chromium, forming chromic iron; with copper, forming red-short iron; with lead and other metals, forming cold-short iron. These alloys often cause cast iron to be hard as well as brittle.

Wrought iron, as it is termed, is cast iron that has been deprived of its carbon and some of its other impurities. This is done by burning the carbon from the cast iron in a current of highly-heated air in a reverbatory furnace. The iron is melted in the furnace, and is stirred and boiled up and exposed to the heated air by means of long puddling bars, as they are termed. After it has been stirred and boiled until it ceases to be fluid, it is then worked into balls, and is taken out of the furnace while white-hot, and crushed in the squeezers or under the trip-hammer, to force out the slag and convert it into blooms. It is then run through grooved rolls to bring the particles of iron nearer each other and give it a fibrous structure; and by means of rolling, it is converted into bar iron, sheet iron, etc. It is then malleable and ductile, and can be forged and welded; yet in balling and puddling cast iron to convert it into wrought iron, it is impossible to separate or burn away all of the impurities, or other metals that may be alloyed with the cast iron, so that in wrought iron, as in cast iron, we have three divisions of iron — as red-short, cold-short, and neutral iron. The red-short iron is an iron that is brittle when red-hot, and strong when cold. This class

of iron is not used for bar iron or any other iron that requires to be heated or forged, but it is principally used for sheet iron, cut-nails, etc. Cold-short iron is an iron that is brittle when cold, but is very tough when hot. This quality fits it for forging better than any other iron, but as it has very little strength when cold, it is seldom used alone except for cheap grades of bar iron. Neutral iron is an iron that is neither brittle when cold or hot, but is between the extreme red-short and cold-short irons, and it is made by mixing the red-short and cold-short irons together. The neutral iron is the best iron for all kinds of bar iron, and all our best bar is made from it.

Steel is an iron that contains less carbon than cast iron, and more than wrought iron. It is made by converting cast iron into wrought iron, and then adding a small percentage of carbon by heating wrought iron bars in a box or oven surrounded by charcoal. These bars of carbonized iron are then melted into crucibles and cast into ingots, and are called cast steel ingots; hence the term cast steel. It is said that the inventor of cast steel was a watchmaker named Huntsman, who lived at Attercliffe, near Sheffield, in England, in the year 1760. He became dissatisfied with the watch-springs in use, and set himself to the task of making them homogeneous;— if he could melt a piece of steel and cast it into an ingot, its composition would be the same throughout. He succeeded; his steel became famous, and Huntsman's ingots were in universal demand. The value of steel depends largely upon its temper; too much carbon causes the steel to be poor and too much like cast iron; too little carbon causes the steel to be like poor wrought iron; hence the importance of having just the proper amount of carbon. Steel is tempered by heating and cooling it suddenly by plunging it into cold water, oil, damp sand or anything that will draw heat from it suddenly. The workmen decide the quality of the temper by the color of the oxide that forms on the surface of the various kinds of work requiring different tempers. Cold chisels and machinists' tools require a straw-blue tint; razors require a straw-yellow; springs and swords a bright blue, and saws a dark blue.

In the last few years several new processes of making steel direct from the pig iron, have been introduced, and are now in operation. The principal process in use

at the present time is the Bessemer process. This process of making steel consists in melting several tons of pig iron in a cupola, and pouring it into a large converter, hung on two pivots, so as to be easily tilted. Air is driven into the converter through the bottom, and is forced up through the molten metal, causing it to bubble and boil, and producing an intense combustion. The roar of the blast, the hot, white flakes of slag, ever and anon whirled upward, the long flame streaming out of the top of the converter, variegated by tints of different metals, and full of sparks of scintillating iron, all show the play of tremendous chemical force. The operation takes about twenty minutes, when the iron is purified of its carbon; silex, and enough speigeleisen cast iron — an iron rich in carbon and manganese — is then added to convert it into steel. Then it is poured out and cast into ingots. It is then hammered or rolled into any desired shape. The Bessemer steel is principally used for railroad steel rails.

Cast iron is iron combined with some four or five per cent. of impurities. With a view of getting rid of the four or five per cent. of impurities contained in cast iron, and giving us a purer wrought iron, the puddling process was invented by Richard Corts. The steam jet and atmospheric-air process was invented by Mr. Plant. The process of applying either air or steam from below, was invented by Mr. Martin. The process of refining iron by a process of granulation was invented by Mr. Clay; and several other processes of refining iron have been invented. The object of all these inventors has been to rob the cast iron of its four or five per cent. of carbon, or impurities. That this four or five per cent. of carbon in cast iron is not barren of all good results, will be seen by a consideration of the products made of cast iron and wrought iron respectively. Cast iron, by losing its carbon loses its fluidity, and wrought iron is almost infusible; yet, by virtue of its malleability and power of adhesion under the operation of welding, wrought iron may be converted into a multitude of useful forms.

NOTES ON IRON—(HAMILTON.)

CAST IRON.

Green-sand iron castings are 6 per cent. stronger than dry sand, and 30 per cent. stronger than chilled; but when castings are chilled and annealed as in car wheels, a gain of 115 per cent. is attained over green-sand castings.

A mixture of 30 per cent. of wrought iron with cast-iron, carefully fused in a crucible, increases strength of cast-iron one third.

Chilling the underside of cast-iron, materially increases its strength.

Chilled bars of cast-iron deflect more readily than unchilled.

Girders cast with face up are stronger than when cast on side, as 1 to .96, also strongest when cast with bottom flange up.

The mean tensile strength of cast-iron is from 16,000 to 20,000 lbs. The value of it, when subjected to a tensile strain may be safely estimated at from ¼ to ⅓ of this or its breaking strain.

Extension of cast-iron, at its limit of elasticity, is estimated at the 1200th part of its length. The ultimate extension is the 500th part of its length.

Cast-iron, at 2.5 tons per square inch, will extend same as wrought-iron at 5.6 tons.

Mean strength of American cast-iron, determined by Major Wade for the ordnance Corps, is 31.829 lbs. per sq. in. of section. Major Rodman—Richmond iron, 37.744 lbs.; mean of English cast-iron (R. R. Coms., 1849), 19,484 lbs; English gun metal (Woolwich Arsenal, 1858), 23,257 lbs.

The resistance to compression is greater than to extension. A cast-iron beam will bend with one-third of its breaking weight, if the load is laid on gradually—one-sixth if laid on at once, will produce same effect, hence should be capable of bearing six times the greatest weight which can be laid on it.

In cast-iron the 1-20 to 1-30 of the breaking weight will give a visible set.

Cast and wrought-iron beams, having similar resistances, have weights as 2.44 to 1.

Girders of cast-iron, up to 40 feet, cost less than wrought-iron; best form of section is Hodgkinson I; when subject to a fixed load, flange should be as 1 to 6; when to concussion, as 1 to 4.

Cast-iron will expand or contract for each degree of heat 0.00000617 3, or the 162000 of its length; shrinks in cooling from 0.0104 to 0.0118 of its length; will contract or expand in the extreme ranges of temperature of this country, the 1157th part of its length, or with a force equal to 4¾ tons per square inch.

Mean strength of American wrought-iron is 55,900; English 53,900. Ultimate extension of wrought-iron is 600th part of its length.

Breaking strain is from ¼ to ⅓ mean strength.

Resistance to flexure, acting evenly over the surface, equals ½ the tensile strength.

Bars of wrought-iron will expand or contract 151200ths of their length for each degree of heat. With range of temperature of this country (—20 to + 120°)= 140°, will expand or contract 1080th of its length, equal to a force 20,740 lbs. or 9¼ tons per square inch of section. Tensile strength increases in from 1 to 6 re-heatings and rollings, from 43,904 lbs. to 61,824 lbs.; in from 6 to 12, is reduced again to 43,904.

In iron the tensile strength for 60° Fahr. is 1; 114, 1.14; 212°, 1.2; 250°, 1.32; 270°, 1.35; 325°, 1.41; 435°, 1.4.

TABLE OF WEIGHT OF CAST IRON.*

The weight of a pattern of perfectly dry white pine, if multiplied by 20 will give approximately the weight of the casting. If well seasoned, but still not perfectly dry, multiply by 19 or by 18.

Assuming 450 lbs. to a cubic ft., a pound contains 3.8400 cubic inches; a ton 5 cubic ft; and a cubic inch weighs .2604 lbs.

Thickness or Diameter in Inches.	Thickness or Diam. in decimals of a foot.	Wt. of a Square Foot. Lbs.	Wt. of a Square bar 1 ft. long. Lbs.	Wt. of a Round bar 1 ft long. Lbs.	Wt. of Balls. Lbs.	Thickness or Diam. in Inches	Thickness or Diam. in decimals of a foot.	Wt. of a Square Foot. Lbs	Wt. of a Square bar 1 ft. long. Lbs.	Wt. of a Round bar 1 ft long. Lbs.	Wt. of Balls. Lbs.
1-32	.0026	1.173	.003	.002		3. 1/8	.2604	117.3	30.52	23.97	4.162
1-16	.0052	2.344	.012	.010		1/4	.2708	121.8	33.01	25.93	4.681
3-32	.0078	3.516	.027	.021	.0001	3/8	.2813	126.5	35.60	27.95	5.243
1/8	.0104	4.687	.048	.038	.0003	1/2	.2917	131.2	38.28	30.07	5.846
5-32	.0130	5.861	.076	.060	.0005	5/8	.3021	135.9	41.07	32.25	6.498
3-16	.0156	7.032	.110	.086	.0009	3/4	.3125	140.6	43.95	34.51	7.193
7-32	.0182	8.203	.150	.118	.0014	7/8	.3229	145.3	46.93	36.85	7.934
1/4	.0208	9.375	.195	.154	.0021	4.	.3333	150.0	50.01	39.27	8.726
9-32	.0234	10.54	.247	.194	.0030	1/8	.3438	154.7	53.18	41.77	9.572
5-16	.0260	11.73	.305	.240	.0042	1/4	.3542	159.3	56.46	44.33	10.47
11-32	.0287	12.89	.370	.290	.0056	3/8	.3646	164.0	59.82	46.99	11.42
3/8	.0313	14.06	.440	.346	.0072	1/2	.3750	168.7	63.33	49.71	12.43
13-32	.0339	15.24	.516	.400	.0092	5/8	.3854	173.4	66.86	52.52	13.49
7-16	.0365	16.41	.598	.470	.0114	3/4	.3958	178.1	70.52	55.39	14.62
15-32	.0391	17.56	.687	.540	.0140	7/8	.4063	182.8	74.28	58.34	15.81
1/2	.0417	18.75	.781	.610	.0170	5.	.4167	187.5	78.12	61.37	17.05
9-16	.0469	21.10	.989	.777	.0243	1/8	.4271	192.2	82.10	64.47	18.35
5/8	.0521	23.44	1.221	.959	.0334	1/4	.4375	196.9	86.14	67.65	19.73
11-16	.0573	25.79	1.478	1.161	.0444	3/8	.4479	201.6	90.29	70.52	21.18
3/4	.0625	28.12	1.758	1.381	.0575	1/2	.4583	206.2	94.54	74.26	22.68
13-16	.0677	30.47	2.064	1.621	.0732	5/8	.4688	210.9	98.89	77.66	24.27
7/8	.0729	32.81	2.393	1.880	.0913	3/4	.4792	215.6	103.3	81.16	25.93
15-16	.0781	35.16	2.747	2.158	.1124	7/8	.4896	220.3	107.9	84.72	27.41
1.	.0833	37.50	3.125	2.455	.1363	6.	.5000	225.0	112.5	88.36	29.44
1-16	.0885	39.84	3.528	2.771	.1636	1/4	.5208	234.4	122.1	95.89	33.28
1/8	.0938	42.19	3.955	3.107	.1942	1/2	.5417	243.8	132.0	103.7	37.44
3-16	.0990	44.53	4.407	3.461	.2284	3/4	.5625	253.1	142.4	111.9	41.94
1/4	.1042	46.87	4.883	3.835	.2664	7.	.5833	262.5	153.2	120.2	46.77
5-16	.1094	49.22	5.384	4.229	.3084	1/4	.6042	271.9	164.2	129.0	51.97
3/8	.1146	51.57	5.909	4.640	.3546	1/2	.6250	281.3	175.8	138.1	57.54
7-16	.1198	53.91	6.461	5.073	.4058	3/4	.6458	290.7	187.7	147.4	63.47
1/2	.1250	56.26	7.033	5.523	.4603	8.	.6667	300.0	200.1	157.0	69.82
9-16	.1302	58.60	7.632	5.993	.5204	1/4	.6875	309.4	212.7	167.0	76.58
5/8	.1354	60.94	8.253	6.484	.5852	1/2	.7083	318.8	225.8	177.3	83.74
11-16	.1406	63.28	8.900	6.991	.6555	3/4	.7292	328.2	239.3	187.9	91.35
3/4	.1458	65.63	9.572	7.518	.7310	9.	.7500	337.4	253.1	198.8	99.42
13-16	.1510	67.97	10.27	8.064	.8122	1/4	.7708	346.8	267.4	210.0	107.9
7/8	.1563	70.32	10.99	8.630	.8991	1/2	.7917	356.2	282.1	221.5	116.8
15-16	.1615	72.66	11.73	9.215	.9920	3/4	.8125	365.6	297.0	233.3	126.3
2.	.1667	75.01	12.50	9.821	1.073	10.	.8333	375.0	312.5	245.5	136.3
1/8	.1771	79.70	14.11	11.09	1.308	1/4	.8542	384.4	328.4	257.8	146.8
1/4	.1875	84.40	15.83	12.43	1.554	1/2	.8750	393.7	344.5	270.6	157.9
3/8	.1979	89.07	17.63	13.85	1.827	3/4	.8958	403.1	361.2	283.7	169.3
1/2	.2083	93.75	19.54	15.34	2.131	11.	.9167	412.5	378.2	297.0	181.5
5/8	.2188	98.44	21.54	16.56	2.467	1/4	.9375	421.9	395.5	310.6	194.2
3/4	.2292	103.2	23.64	18.56	2.835	1/2	.9583	431.2	413.3	324.6	207.3
7/8	.2396	107.8	25.84	20.29	3.241	3/4	.9792	440.6	431.4	338.8	219.2
3.	.2500	112.6	28.13	22.10	3.682	12.	1 Foot	450.	450.	353.4	235.6

* For Copper, multiply by 1.2; Lead, multiply by 1.6; Brass, add 1-7th; Zinc, multiply by .97. All approximate.

TABLE OF WEIGHT OF WROUGHT IRON* AND STEEL.

Wrought iron is here taken at 485 lbs. per cub. ft. Very pure soft wrought iron weighs from 488 to 492 lbs. per cubic foot Light weight indicates impurities, and weakness. Steel weighs about 490 lbs. per cubic foot; therefore, FOR STEEL, AN ADDITION MUST BE MADE TO THE TABULAR AMOUNTS, OF ABOUT 1 POUND IN 100 LBS.

At 485 lbs. per cub. ft., a cubic inch weighs .28067 lb.; a lb. contains 3.5629 cub. ins., and a ton, 4.6186 cub. ft.; and this is about the average of *Hammered* iron. The usual assumption is 480 lbs., per cub. ft.; which is nearer the average of ordinary *rolled* iron. At 480 lbs., a cubic inch weighs .2778 of a lb.; a lb. contains 3 6 cub. ins.; a ton, 4 6667 cub. ft.; a rod of 1 sq. inch area, weighs 10 lbs. per yard; or 3⅓ lbs. per foot, exactly.

Thickness or Diameter in Inches.	Thickness or Diam. in decimals of a foot.	Wt. of a Square Foot. Lbs.	Wt. of a square bar, 1 ft. long. Lbs.	Wt. of a Round bar 1 ft. long. Lbs.	Wt. of Balls. Lbs.	Thickness or Diam. in Inches	Thickness or Diam. in decimals of a foot.	Wt. of a Square Foot. Lbs.	Wt. of a Square bar 1 ft. long. Lbs.	Wt. of a Round bar, 1 ft. long. Lbs.	Wt. of Balls. Lbs.
1-32	.0026	1.263	.0033	.0026		3.⅛	.2604	126.3	32.86	25 83	4 484
1-16	.0052	2 526	.0132	.0104		¼	.2708	131.4	35.57	27.94	5.045
3-32	.0078	3.789	.0296	.0233	.0001	⅜	.2813	136.4	38.37	30.13	5.649
⅛	.0104	5.052	.0526	.0414	.0003	½	.2917	141.5	41.26	32.41	6.301
5-32	.0130	6 315	.0823	.0646	.0005	⅝	.3021	146.5	44.26	34.76	7.000
3-16	.0156	7.578	.1184	.0930	.0009	¾	.3125	151.6	47.37	37.20	7.750
7-32	.0182	8.841	.1612	.1266	.0015	⅞	.3229	156.6	50.57	39 72	8.550
¼	.0208	10.10	.2105	.1653	.0023	4.	.3333	161.7	53.89	42.33	9.405
9-32	.0234	11.37	.2665	.2093	.0033	⅛	.3438	166 7	57.31	45.01	10.32
5-16	.0260	12 63	.3290	.2583	.0045	¼	.3542	171.8	60.84	47.78	11.28
11-32	.0287	13.89	.3980	.3126	.0060	⅜	.3646	176.8	64.47	50.63	12.31
⅜	.0313	15.16	.4736	.3720	.0078	½	.3750	181.9	68.20	53 57	13 39
13-32	.0339	16.42	.5558	.4365	.0098	⅝	.3854	186.9	72.05	56.59	14.54
7-16	.0365	17.68	.6446	.5063	.0123	¾	.3958	192.0	76.99	59.69	15 75
15-32	.0391	18.95	.7400	.5813	.0151	⅞	.4063	197.0	80.05	62.87	17 03
½	.0417	20.21	.8420	.6613	.0184	5.	.4167	202.1	84.20	66.13	18.37
9-16	.0469	22.73	1.066	.8370	.0262	⅛	.4271	207.1	88.47	69.48	19.78
⅝	.0521	25.26	1.316	1.033	.0359	¼	.4375	212.2	92.83	72.91	21.26
11-16	.0573	27.79	1.592	1 250	.0478	⅜	.4479	217.2	97.31	76.43	22.82
¾	.0625	30.31	1.895	1.488	.0620	½	.4583	222.3	101.9	80.02	24 45
13-16	.0677	32.84	2.223	1.746	.0788	⅝	.4688	227.3	106.6	83.70	26.16
⅞	.0729	35.37	2.579	2.025	.0985	¾	.4792	232.4	111.4	87.46	27.94
15-16	.0781	37.89	2.960	2.325	.1211	⅞	.4896	237.5	116.3	91.31	29 80
1.	.0833	40.42	3.368	2 645	.1470	6.	5000	242.5	121.3	95.23	31.74
1-16	.0885	42.94	3.803	2.986	.1763	¼	.5208	252.6	131.6	103.3	35.88
⅛	.0938	45.47	4.263	3.348	.2093	½	.5417	262.7	142.3	111.8	40.36
3-16	.0990	48.00	4.750	3.730	.2461	¾	.5625	272.8	153 5	120 5	45.19
¼	.1042	50.52	5.263	4.133	.2870	7.	.5833	282.9	165.0	129.6	50 40
5-16	.1094	53.05	5.802	4.557	.3323	¼	.6042	293.0	177.0	139.0	56.00
⅜	.1146	55.57	6.368	5.001	.3820	½	.6250	303.1	189.5	148.8	62.00
7-16	.1198	58.10	6.960	5.466	.4365	¾	.6458	313.2	202.3	158.9	68.40
½	.1250	60.63	7.578	5.952	.4960	8.	.6667	323 3	215 6	169.3	75.24
9-16	.1302	63.15	8.223	6.458	.5606	¼	.6875	333.4	229.3	180.1	82.52
⅝	.1354	65.68	8.893	6.985	.6306	⅛	.7083	343.5	243.4	191.1	90.25
11-16	.1406	68.20	9.591	7.533	.7062	¾	.7292	353.6	24 .9	202.5	98.45
¾	.1458	70.73	10.31	8.101	.7876	9.	.7500	363 8	272.8	214.3	107.1
13-16	.1510	73.26	11.07	8.690	.8750	¼	.7708	373.9	288.2	226.3	116.3
⅞	.1563	75 78	11.84	9.300	.9688	½	.7917	384.0	304 0	238.7	126.0
15-16	.1615	78 31	12.64	9.930	1.069	¾	.8125	394.1	320 2	251.5	136.2
2.	.1667	80.83	13.47	10.58	1.176	10.	.8333	404.2	3 6.8	264.5	146.9
⅛	.1771	85.89	15.21	11.95	1.410	¼	.8542	414.3	353.9	277.9	158.2
¼	.1875	90.94	17.05	13.39	1.674	½	.8750	424.4	371.3	291.6	170.1
⅜	.1979	95.99	19.00	14 92	1 969	¾	.8958	434.5	389.2	305.7	182.6
½	.2083	101.0	21.05	16.53	2.296	11.	.9167	444 6	407.5	320.1	195.6
⅝	.2188	106.1	23.21	18.23	2.658	¼	.9375	454.7	426.3	334.8	209.2
¾	.2292	111.2	25 47	20.01	3.056	½	.9583	464 8	445 4	349.8	223 5
⅞	.2396	116.2	27.84	21.87	3.492	¾	.9792	474.9	465.0	365.2	238.4
3.	.2500	121.3	30.31	23.81	3.968	12.	1 Foot	485.0	485.0	380.9	253.9

*For Copper, add 1-7 part; Lead, multiply by 1.47; Brass, multiply by 1.06; Zinc, multiply by .9; Tin, multiply by 95. All approximate.

WEIGHT OF SHEET METALS.

Weight of one square foot of Rolled, or Sheet Iron, Steel or Brass Plates.—(From Haswell.)

Thickness by the Birmingham gauge for iron wire, sheet-iron and steel.

For rolled lead, multiply copper by 1.3; and for zinc, multiply wrought iron by the decimal .9.

Gauge.	Thickness.	Iron.	Steel.	Copper.	Brass.
No	In.	Lbs.	Lbs.	Lbs.	Lbs.
000	.425	17.18	17.35	19.2525	18.1900
00	.380	15.36	15.51	17.2140	16.2640
0	.340	13.74	13.87	15.4020	14.5520
1	.300	12.13	12.25	13.5900	12.8400
2	.284	11.48	11.59	12.8652	12.1552
3	.259	10.47	10.57	11.7327	11.0852
4	.238	9.619	9.715	10 7814	10.1864
5	.220	8.892	8.981	9.9660	9 4160
6	.203	8.205	8.287	9.1959	8.6884
7	.180	7.275	7.348	8.1540	7.7040
8	.165	6.669	6.736	7.4745	7.0620
9	.148	5.981	6.041	6.7044	6.3344
10	.134	5.416	5.470	6.0702	5.7352
11	.120	4.850	4.899	5.4360	5.1360
12	.109	4.405	4.449	4.9377	4.6652
13	.095	3.840	3.878	4.3035	4.0660
14	.083	3.355	3.388	3.7599	3.5524
15	.072	2.910	2.939	3.2616	3.0816
16	.065	2.627	2.653	2.9445	2.7820
17	.058	2.344	2.367	2.6274	2.4824
18	.049	1.980	1.999	2.2197	2.0972
19	.042	1.697	1.714	1.9026	1.7976
20	.035	1.415	1.429	1.5855	1.4980
21	.032	1.293	1.305	1.4496	1.3696
22	.028	1.132	1.143	1.2684	1.1984
23	.025	1.010	1.020	1.1325	1.0700
24	.022	.8892	.8981	.9966	.9413
25	.020	.8083	.8164	.9060	.8560
26	.018	.7225	.7348	.8154	.7704
27	.016	.6467	.6532	.7428	.6848
28	.014	.5658	.5715	.6342	.5992
29	.013	.5254	.5307	.5889	.5564
30	.012	.4850	.4899	.5436	.5136
31	.010	.4042	.4082	.4530	.4280
32	.009	.3638	.3674	.4077	.3852
33	.008	.3233	.3265	.3624	.3424
34	.007	.2829	.2857	.3171	.2996
35	.005	.2021	.2041	.2265	.2140
36	.004	.1617	.1633	.1812	.1712

Thickness by Brown & Sharpe's Gauge

For rolled lead, multiply copper by 1.3; and for zinc, multiply wrought iron by the decimal .9. Silver is 1/8 heavier than steel.

Gauge.	Thickness.	Iron.	Steel.	Copper	Brass.
No	Ins.	Lbs.	Lbs.	Lbs.	Lbs.
000	.40964	16.58	16.80	18.5567	17.5326
00	.36480	14.77	14.96	16.5254	15.6134
0	.32486	13.15	13 32	14.7162	13.9040
1	.28930	11.70	11.86	13.1053	12.3820
2	.25763	10.43	10.57	11.6706	11.0266
3	.22942	9.291	9.415	10.3927	9.8192
4	.20431	8.273	8.384	9.2552	8.7445
5	.18194	7.366	7.462	8.2419	7.7870
6	.16202	6.561	6.648	7.3395	6.9345
7	.14428	5.842	5.920	6.5359	6.1752
8	.12849	5.203	5.272	5.8206	5.4994
9	.11443	4 633	4.695	5.1837	4.8976
10	.10189	4.125	4.180	4.6156	4.3609
11	.090742	3.672	3.723	4.1106	3.8838
12	.080808	3.272	3.315	3 6606	3.4586
13	.071961	2.916	2.952	3.2598	3.0799
14	.064084	2.592	2.629	2.9030	2.7428
15	.057068	2.311	2.341	2.5852	2.4425
16	.050820	2.052	2.085	2.3021	2.1751
17	.045257	1.825	1.857	2.0501	1.9370
18	.040303	1.631	1.653	1.8257	1.7250
19	.035890	1.452	1.468	1.6258	1.5361
20	.031961	1.293	1.311	1.4478	1 3679
21	.028462	1.152	1.166	1.2893	1.2182
22	.025347	1.026	1.040	1.1482	1.0849
23	022571	.913	.925	1.0225	.96604
24	020100	.814	.824	.91053	.86028
25	.017900	.724	.734	.81087	.76612
26	015940	.644	.653	.72208	.68223
27	014195	.574	.582	.64303	.60755
28	.012641	.511	.518	.57264	.54103
29	.011257	.455	.471	.50994	.48180
30	.010025	.405	.410	.45413	.42907
31	.008928	.360	.366	.40444	.38212
32	.007950	.321	.326	.36014	.34026
33	.007080	.286	.290	.32072	.30302
34	.006304	.254	.258	.28557	26981
35	.005614	.226	.230	.25431	.24028
36	005000	.202	.205	.2265	.21400
37	.004453	.180	.182	.20172	.19059
38	.003965	.159	.162	.17961	.16970
39	.003531	.142	.144	.15995	.15113
40	.003144	.127	.128	.14242	.13456

WEIGHT of ANGLE and TEE IRON—One Foot in Length.

NOTE.—When the base or web tapers in section, the mean thickness is to be measured.

Sum of the Width and Depth in Inches.

Thickness.	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾
⅛	.57	.62	.68	.73	.78	.83	.88	.94	.99	1.04	1.09
3/16	.81	.89	.97	1.05	1.13	1.21	1.29	1.37	1.45	1.52	1.60
¼	1.04	1.15	1.25	1.36	1.46	1.56	1.67	1.77	1.88	1.98	2.08
5/16	1.24	1.37	1.50	1.63	1.76	1.89	2.02	2.15	2.28	2.41	2.54

Thickness.	2⅞	3	3⅛	3¼	3⅜	3½	3⅝	3¾	3⅞	4	4¼
⅛	1.14	1.20	1.25	1.30	1.45	1.41	1.46	1.51	1.56	1.62	1.72
3/16	1.68	1.76	1.84	1.91	1.99	2.07	2.15	2.23	2.30	2.38	2.54
¼	2.19	2.29	2.40	2.50	2.60	2.71	2.81	2.92	3.02	3.13	3.33
5/16	2.67	2.80	2.93	3.06	3.19	3.32	3.45	3.58	3.71	3.84	4.10
⅜	3.13	3.28	3.44	3.59	3.75	3.91	4.06	4.22	4.38	4.53	4.84
7/16	3.57	3.75	3.93	4.11	4.29	4.48	4.66	4.84	5.02	5.20	5.56

Thickness.	4½	4¾	5	5¼	5½	5¾	6	6¼	6½	6¾	7
3/16	2.70	2.85	3.01	3.16	3.32	3.48	3.63	3.79	3.95	4.10	4.26
¼	3.54	3.75	3.96	4.17	4.38	4.58	4.79	5.00	5.21	5.42	5.63
5/16	4.36	4.62	4.88	5.14	5.40	5.66	5.92	6.18	6.45	6.71	6.97
⅜	5.16	5.47	5.78	6.09	6.41	6.72	7.03	7.34	7.66	7.97	8.28
7/16	5.92	6.29	6.65	7.02	7.38	7.75	8.11	8.48	8.84	9.21	9.57
½	6.67	7.08	7.50	7.92	8.33	8.75	9.17	9.58	10.00	10.42	10.83
9/16	7.38	7.85	8.32	8.79	9.26	9.73	10.20	10.66	11.13	11.60	12.07

Thickness.	7¼	7½	7¾	8	8¼	8½	8¾	9	9¼	9½	9¾
¼	5.83	6.04	6.25	6.46	6.67	6.88	7.08	7.29	7.50	7.71	7.92
5/16	7.23	7.49	7.75	8.01	8.27	8.53	8.79	9.05	9.31	9.57	9.83
⅜	8.59	8.91	9.22	9.53	9.84	10.16	10.47	10.78	11.09	11.41	11.72
7/16	9.93	10.30	10.66	11.03	11.39	11.76	12.12	12.49	12.85	13.22	13.58
½	11.25	11.67	12.08	12.50	12.92	13.33	13.75	14.17	14.58	15.00	15.42
9/16	12.54	13.01	13.48	13.94	14.41	14.88	15.35	15.82	16.29	16.76	17.23
⅝	13.80	14.32	14.84	15.36	15.89	16.41	16.93	17.45	17.97	18.49	19.01

Thickness.	10	10½	11	11½	12	12½	13	13½	14	14½	15
⅜	12.03	12.66	13.28	13.91	14.53						
7/16	13.95	14.67	15.40	16.31	16.86	17.59	18.31	19.04	19.77	20.50	21.22
½	15.83	16.67	17.50	18.33	19.17	20.00	20.84	21.67	22.50	23.34	24.17
9/16	17.70	18.63	19.57	20.51	21.44	22.38	23.31	24.25	25.19	26.12	27.06
⅝	19.53	20.57	21.61	22.66	23.70	24.74	25.78	26.83	27.87	28.91	29.95
¾	23.13	24.38	25.63	26.88	28.13	29.37	30.63	31.88	33.13	34.38	35.63

Thickness.	12	12½	13	13½	14	15	16	17	18	19	20
⅝	23.70	24.74	25.78	26.83	27.87	29.95	32.03	34.12	36.20	38.28	40.36
¾	28.13	29.37	30.63	31.88	33.13	35.63	38.13	40.63	41.13	43.63	46.13
⅞	32.45	33.91	35.36	36.82	38.28	41.19	44.12	47.02	49.95	52.87	55.78
1	36.67	38.33	40.00	41.67	43.33	46.67	50.00	53.33	56.67	60.00	63.33

From D. K. CLARK's Rules, Tables, and Data.

WEIGHT OF ONE FOOT IN LENGTH OF WIRE, OF IRON, STEEL OR COPPER. (From Haswell.)

Diameters by the Birmingham gauge for iron wire, sheet iron, and steel.					Diameters by Brown & Sharpe's gauge.				
No. of Gauge.	Diam.	Iron.	Steel.	Copper.	No. of Gauge.	Diam.	Iron.	Steel.	Copper.
	Ins.	Lbs.	Lbs.	Lbs.		Ins	Lbs.	Lbs.	Lbs.
0000	.454	.546207	.551360	.623913	0000	.46000	.56074	.566030	.640513
000	.425	.478656	.483172	.546752	000	.40964	.444683	.448879	.507946
00	.380	.382660	.386270	.437099	00	.36480	.352659	355986	.402830
0	.340	.306340	.309230	.349921	0	.32486	.279665	.282303	.319451
1	.300	.238500	.240750	.272430	1	.28930	.221786	.223891	.253342
2	.284	.213738	215755	.244146	2	.25763	.175888	.177548	.200911
3	.259	.177765	.179442	.203054	3	.22942	.139480	140796	.159323
4	.238	.150107	.151523	.171461	4	.20431	.110616	.111660	.126353
5	.220	128260	129470	.146507	5	.18194	.087720	.088548	.100200
6	.203	.109204	.110234	.124740	6	.16202	.069565	.070221	.079462
7	.180	.085860	086667	.098075	7	.14428	.055165	055685	.063013
8	.165	.072146	.072827	.082410	8	.12849	.043751	.044164	.049976
9	.148	.058046	.058593	066303	9	.11443	.034699	.035026	.039636
10	.134	.047583	.048032	.054353	10	.10189	.027512	.027772	.031426
11	.120	.038160	.038520	.043589	11	.090742	.021820	022026	.024924
12	.109	.031485	.031782	.035964	12	.080808	.017304	.017468	.019766
13	.095	.023916	.024142	.027319	13	.071961	.013722	.013851	.015674
14	.083	.018256	.018428	.020853	14	.064084	.010886	.010989	.012435
15	.072	013738	.013867	.015693	15	.057068	.008631	.008712	.009859
16	.065	.011196	.011302	.012789	16	.050820	.006845	.006909	.007819
17	.058	.008915	.008999	.010183	17	.045257	.005427	.005478	.006199
18	.049	006363	.006423	007268	18	.040303	004304	.004344	.004916
19	.042	.004675	.004719	.005340	19	.035890	.003413	.003445	.003899
20	.035	.003246	.003277	.003708	20	.031961	002708	002734	.003094
21	.032	.002714	.002739	.003100	21	.028462	.002147	002167	.002452
22	.028	.002078	002097	.002373	22	.025347	001703	.001719	.001945
23	.025	.001656	001672	.001892	23	.022571	.001350	001363	.001542
24	.022	.001283	.001295	.001465	24	.020100	.001071	.001081	.001223
25	.020	.001060	.001070	.001211	25	.017900	.0008491	.0008571	.0009699
26	.018	.0008586	.0008687	.0009807	26	.015940	.0006734	.0006797	.0007692
27	.016	.0006784	.0006848	.0007749	27	014195	.0005340	.0005391	.0006099
28	.014	0005194	.0005243	.0005933	28	.012641	.0004235	.0004275	.0004837
29	.013	.0004479	.0004521	.0005116	29	011257	.0003358	.0003389	.0003835
30	.012	.0003816	0003852	.0004359	30	.010025	.0002663	.0002688	0003042
31	.010	.0002650	0002675	.0303027	31	.008928	.0002113	.0002132	0002413
32	.009	.0002147	.0002167	.0002452	32	.007950	.0001675	0001691	.0001913
33	.808	.0001696	.0001712	.0001937	33	.007080	.0001328	.0001341	.0001517
34	.007	.0001299	.0001311	.0001483	34	.006304	.0001053	0001063	.0001204
35	.005	.00006625	.00006688	.00007568	35	.005614	.00008366	00008445	.0000956
36	.004	.0000424	.0000428	00004843	36	.005000	.00006625	.00006687	.0000757
Sp. gravy		7 77	7.85	8.89	37	.004453	.00005255	.00005304	00006003
					38	.003965	.00004166	00004205	.00004758
Wts. of a cubic foot		485 *	490.	555.	39	003531	.00003305	.00003336	.00003775
cub. in		.2807	.2836	3212	40	003144	.00002620	.00002644	.00002992

WIRE GAUGES, NOS. AND SIZES.

Number.	Birmingham, or Stub's Gauge.	Brown & Sharpe's Gauge.	Washburn & Moen's Gauge.	Trenton Iron Co's Gauge.
7–0			.490	
6–0			.460	
5–0			.430	.450
4–0	.454	.46000	.393	.400
3–0	.425	.40964	.362	.360
2–0	.380	.36480	.331	.330
1–0	.340	.32495	.307	.305
1	.300	.28930	.283	.285
2	.284	.25763	.263	.265
3	.259	.22942	.244	.245
4	.238	.20431	.225	.225
5	.220	.18194	.207	.205
6	.203	.16202	.192	.190
7	.180	.14428	.177	.175
8	.165	.12849	.162	.160
9	.148	.11443	.148	.145
10	.134	.10189	.135	.130
11	.120	.09074	.120	.1175
12	.109	.08081	.105	.1050
13	.095	.07196	.092	.0925
14	.083	.06408	.080	.0800
15	.072	.05707	.072	.0700
16	.065	.05082	.063	.0610
17	.058	.04526	.054	.0525
18	.049	.04030	.047	.0450
19	.042	.03589	.041	.0400
20	.035	.03196	.035	.0355
21	.032	.02846	.032	.0310
22	.028	.02535	.028	.0280
23	.025	.02257	.025	.0250
24	.022	.02010	.023	.0225
25	.020	.01790	.020	.02075
26	.018	.01594	.018	.01900
27	.016	.01419	.017	.01750
28	.014	.01264	.016	.01650
29	.013	.01126	.015	.01550
30	.012	.01002	.014	.01450
31	.010	.00893	.0135	.01375
32	.009	.00795	.013	.01300
33	.008	.00708	.011	.01200
34	.007	.00630	.010	.01100
35	.005	.00561	.0095	.01000
36	.004	.00500	.009	.00900
37		.00445		.00825
38		.00396		.00775
39		.00353		.00725
40		.00314		.00675

FLAT ROLLED IRON.

Weight of 1 ft. in length, at 480 lbs. per cubic foot. For cast iron, deduct 1-16 part; for steel, add 1-48; for copper, add 1-7; for cast brass, add 1-13; for lead, add, 1-2; for zinc, deduct 1-12.

Width in Ins.	THICKNESS IN INCHES.											
	1-16	⅛	3-16	¼	5-16	⅜	7-16	½	⅝	¾	⅞	1
1.	.2083	.4166	.6250	.8333	1.042	1.250	1.458	1.666	2.083	2.500	2.916	3.333
⅛	.2344	.4688	.7033	.9375	1.172	1.406	1.640	1.875	2.344	2.812	3.280	3.750
¼	.2605	.5210	.7810	1.042	1.303	1.563	1.823	2.083	2.605	3.125	3.646	4.166
⅜	.2865	.5730	.8595	1.146	1.432	1.719	2.006	2.292	2.864	3.438	4.012	4.583
½	.3125	.6250	.9375	1.250	1.562	1.875	2.188	2.500	3.125	3.750	4.375	5.000
⅝	.3385	.6771	1.015	1.354	1.692	2.031	2.370	2.708	3.384	4.062	4.740	5.416
¾	.3646	.7292	1.094	1.458	1.823	2.188	2.550	2.916	3.646	4.375	5.105	5.833
⅞	.3906	.7812	1.172	1.562	1.953	2.344	2.732	3.125	3.906	4.688	5.470	6.250
2.	.4166	.8333	1.25	1.666	2.083	2.500	2.916	3.333	4.166	5.000	5.833	6.666
⅛	.4427	.8855	1.328	1.771	2.214	2.656	3.098	35.42	4.428	5.312	61.96	7.083
¼	.4688	.9375	1.406	1.875	2.344	2.812	3.281	3.750	4.688	5.624	6.562	7.500
⅜	.4948	.9895	1.484	1.979	2.474	2.968	3.463	3.958	4.948	5.936	69.26	7.916
½	.5210	1.042	1.562	2.003	2.605	3.125	3.646	4.166	5.210	6.250	7.291	8.333
⅝	.5470	1.094	1.641	2.187	2.735	3.282	3.829	4.375	5.470	6.564	7.658	8.750
¾	.5730	1.146	1.719	2.292	2.865	3.438	4.011	4.583	5.730	6.876	8.022	9.166
⅞	.5990	1.198	1.797	2.396	2.995	3.594	4.193	4.792	5.990	7.188	8.386	9.583
3.	.625	1.250	1.875	2.500	3.125	3.750	4.375	5.000	6.250	7.500	8.750	10.00
⅛	.6515	1.303	1.954	2.605	3.257	3.908	4.560	5.210	6.514	7.816	9.120	10.42
¼	.6770	1.354	2.031	2.708	3.385	4.062	4.739	5.416	6.770	8.124	9.478	10.83
⅜	.7031	1.406	2.109	2.812	3.516	4.218	4.921	5.625	7.032	8.436	9.842	11.25
½	.7291	1.458	2.188	2.916	3.646	4.375	5.105	5.833	7.291	8.750	10.21	11.66
⅝	.7555	1.511	2.266	3.021	3.777	4.533	5.288	6.042	7.554	9.066	10.58	12.08
¾	.7812	1.562	2.343	3.125	3.906	4.686	5.468	6.250	7.812	9.372	10.94	12.50
⅞	.8070	1.614	2.421	3.229	4.035	4.842	5.650	6.458	8.070	9.684	11.30	12.92
4.	.8333	1.666	2.500	3.333	4.166	5.000	5.833	6.666	8.333	10.00	11.66	13.33
⅛	.8595	1.719	2.578	3.438	4.297	5.156	6.016	6.875	8.594	10.31	12.03	13.75
¼	.8855	1.771	2.656	3.542	4.427	5.312	6.198	7.083	8.854	10.62	12.40	14.16
⅜	.9115	1.823	2.734	3.646	4.557	5.468	6.380	7.291	9.114	10.94	12.76	14.58
½	.9375	1.875	2.812	3.750	4.687	5.624	6.562	7.500	9.374	11.25	13.12	15.00
⅝	.9636	1.927	2.891	3.854	4.818	5.782	6.745	7.708	9.636	11.56	13.49	15.42
¾	.9895	1.979	2.968	3.958	4.947	5.936	6.926	7.917	9.894	11.87	13.85	15.83
⅞	1.016	2.031	3.048	4.062	5.080	6.096	7.112	8.125	10.16	12.19	14.22	16.25
5.	1.042	2.083	3.125	4.166	5.210	6.250	7.291	8.333	10.42	12.50	14.58	16.66
⅛	1.068	2.136	3.204	4.271	5.340	6.408	7.476	8.542	10.68	12.81	14.95	17.08
¼	1.094	2.188	3.282	4.375	5.470	6.564	7.658	8.750	10.94	13.13	15.31	17.50
⅜	1.120	2.240	3.360	4.479	5.600	6.720	7.840	8.958	11.20	13.44	15.68	17.92
½	1.146	2.292	3.438	4.584	5.730	6.876	8.022	9.167	11.46	13.75	16.04	18.33
⅝	1.172	2.344	3.516	4.687	5.860	7.032	8.204	9.375	11.72	14.06	16.40	18.75
¾	1.198	2.396	3.594	4.791	5.990	7.188	8.386	9.583	11.98	14.37	16.77	19.16
⅞	1.224	2.448	3.672	4.896	6.120	7.344	8.568	9.792	12.24	14.69	17.13	19.58
6.	1.250	2.500	3.750	5.000	6.250	7.500	8.750	10.00	12.50	15.00	17.50	20.00
⅛	1.276	2.552	3.828	5.104	6.380	7.656	8.932	10.21	12.76	15.31	17.86	20.42
¼	1.302	2.604	3.906	5.208	6.510	7.812	9.114	10.42	13.02	15.62	18.23	20.83
⅜	1.328	2.657	3.984	5.313	6.640	7.968	9.297	10.63	13.28	15.93	18.59	21.25
½	1.354	2.708	4.063	5.417	6.770	8.126	9.480	10.83	13.54	16.25	18.96	21.66
⅝	1.381	2.761	4.143	5.521	6.906	8.286	9.668	11.04	13.81	16.57	19.33	22.08
¾	1.406	2.813	4.218	5.625	7.030	8.436	9.843	11.25	14.06	16.87	19.69	22.50
⅞	1.432	2.864	4.296	5.729	7.260	8.592	10.02	11.46	14.32	17.18	20.04	22.92
7.	1.458	2.916	4.375	5.833	7.291	8.750	10.20	11.66	14.58	17.50	20.42	23.33
⅛	1.484	2.969	4.452	5.938	7.420	8.904	10.39	11.87	14.84	17.81	20.78	23.75
¼	1.511	3.021	4.533	6.042	7.555	9.066	10.58	12.08	15.11	18.13	21.16	24.16
⅜	1.536	3.073	4.608	6.146	7.686	9.216	10.75	12.29	15.36	18.43	21.50	24.58
½	1.562	3.125	4.686	6.250	7.810	9.372	10.93	12.50	15.62	18.74	21.86	25.00
⅝	1.588	3.177	4.764	6.354	7.940	9.528	11.12	12.71	15.88	19.05	22.24	25.42
¾	1.615	3.229	4.845	6.458	8.075	9.690	11.31	12.92	16.15	19.38	22.62	25.83
⅞	1.641	3.281	4.923	6.562	8.205	9.846	11.48	13.13	16.41	19.69	22.96	26.25
8.	1.666	3.333	5.000	6.666	8.333	10.00	11.66	13.33	16.66	20.00	23.33	26.66
⅛	1.693	3.386	5.079	6.771	8.455	10.15	11.85	13.54	16.91	20.30	23.70	27.08
¼	1.719	3.438	5.157	6.875	8.595	10.31	12.03	13.75	17.19	20.61	24.06	27.50
⅜	1.745	3.489	5.235	7.979	8.725	10.47	12.21	13.96	17.45	20.94	24.42	27.92

FLAT ROLLED IRON—Concluded.

Weight of 1 foot in length, at 480 lbs. per cubic foot.

Width in Ins.	THICKNESS IN INCHES. 1-16	⅛	3-16	¼	5-16	⅜	7-16	½	⅝	¾	⅞	1
8½	1.771	3.542	5.313	7.083	8.855	10.63	12.40	14.17	17.71	21.26	24.80	28.33
⅝	1.797	3.594	5.391	7.188	8.985	10.78	12.58	14.37	17.97	21.56	25.16	28.75
¾	1.823	3.646	5.469	7.292	9.115	10.94	12.76	14.58	18.23	21.88	25.52	29.17
⅞	1.849	3.698	5.547	7.396	9.245	11.09	12.94	14 79	18.49	22.18	25.88	29.58
9.	1.875	3.750	5.625	7.500	9.375	11.25	13.12	15.00	18.75	22.50	26 24	30.00
⅛	1.901	3.802	5.703	7.604	9.505	11.41	13.31	15.21	19.00	22.81	26.62	30.42
¼	1.927	3.854	5.781	7.708	9.635	11.56	13.49	15.42	19.27	23.12	26.98	30.8
⅜	1.953	3.906	5.859	7.812	9.765	11.72	13.67	15.62	19.53	23.44	27.34	31.25
½	1.979	3.958	5.937	7.916	9.895	11.87	13.85	15.84	19.79	23.74	27.70	31.67
⅝	2.005	4.010	6.015	8.021	10.02	12.03	14.04	16.04	20.04	24.06	28.08	32.08
¾	2.031	4.062	6.093	8.125	10.16	12.18	14.21	16.25	20 32	24.36	28 42	32.50
⅞	2.057	4.114	6.171	8.229	10.29	12.34	14.40	16.46	20.58	24.68	28.80	32.92
10.	2.083	4.166	6.250	8.333	10.41	12.50	14.58	16.66	20.82	25.00	29.16	33 33
⅛	2.109	4.219	6.327	8.438	10.55	12.65	14.76	16.87	21.10	25.30	29.52	33.75
¼	2.135	4.270	6.405	8.541	10.67	12.81	14.94	17.08	21.34	25.62	29.88	34.17
⅜	2.162	4.323	6.486	8.646	10.81	12.97	15 13	17.29	21.62	25 94	30.26	34.58
½	2.188	4.375	6.564	8.750	10.94	13.13	15.31	17.50	21.88	26.26	30.62	35.00
⅝	2.214	4.427	6.642	8.854	11.07	13.28	15.50	17.71	22.14	26.56	31.00	35.42
¾	2.239	4.479	6.717	8.958	11.20	13.43	15.67	17.92	22 40	26.86	31.34	35.83
⅞	2.266	4.531	6.798	9.062	11.33	13.59	15.86	18.12	22.66	27.18	31.72	36.25
11.	2.291	4.583	6.873	9.166	11.46	13.75	16.04	18.33	22.90	27.50	32 08	36 66
⅛	2.318	4.636	6.954	9.271	11.59	13.91	16.22	18.54	23.18	27.82	32.44	37.08
¼	2.344	4.688	7.032	9.375	11.72	14.06	16.40	18.75	23.44	28.12	32.80	37.50
⅜	2.370	4.740	7.110	9.479	11.85	14.22	16.59	18.96	23.70	28.44	33.18	37.92
½	2.395	4.791	7.185	9.582	11.97	14.37	16.76	19.16	23.94	28.74	33.52	38.33
⅝	2.422	4.844	7.266	9.688	12.11	14.53	16.95	19.37	24.22	29.06	33.90	38.75
¾	2.448	4.896	7.344	9.792	12.24	14.68	17.13	19.58	24.48	29.36	34.26	39.16
⅞	2.474	4.948	7.422	9.896	12.37	14 84	17.32	19.79	24.74	29.68	34.64	39 58
12.	2.500	5.000	7.500	10.00	12.50	15.00	17.50	20.00	25.00	30.00	35.00	40.00

WEIGHT AND STRENGTH OF IRON BOLTS.

Ends enlarged, or upset.				Ends not enlarged.		Ends enlarged, or upset.				Ends not enlarged.	
Diam. of Shank.	Weight per foot run.	Breaking strain.	Breaking strain.	Diam. of Shank.	Weight per foot run.	Diam. of Shank.	Weight per foot run.	Breaking strain.	Breaking strain.	Diam. of Shank.	Weight per ft. run.
Inches.	Pounds.	Tons.	Pounds.	Inches.	Pounds.	Inches.	Pounds.	Tons.	Pounds.	Inches.	Pds.
⅛	.0414	.245	549			1¾	8.10	45.7	102368	2.14	12.0
3-16	.093	.553	1239			13-16	8.69	49.0	109760	2.22	12.9
¼	.165	.983	2202	.35	.321	⅞	9.30	52.5	117600	2.30	13.8
5-16	.258	1.53	3427	.43	.452	15-16	9.93	56.0	125440	2.38	14.7
⅜	.372	2.21	4950	.50	.654	2.	10.6	59.7	133728	2.45	15.7
7-16	.506	3.00	6720	.58	.897	⅛	12.0	63.8	142912	2.59	17.5
½	.661	3.93	8803	.66	1.14	¼	13.4	71.6	160384	2.73	19.5
9-16	.837	4.97	11133	.73	1.41	⅜	14.9	79.7	178528	2.88	21.6
⅝	1.03	6.14	13754	.80	1.67	½	16.5	88.4	198016	3.02	23.9
11-16	1.25	7.42	16621	.88	2.03	⅝	18.2	97.4	218176	3.16	26.1
¾	1.49	8.83	19779	.96	2 41	¾	20.0	106.9	239456	3.30	28.5
13-16	1.75	10.4	23296	1.04	2.81	⅞	21.9	116.8	261632	3.45	31.1
⅞	2.03	12.0	26880	1.12	3 26	3.	23.8	127.2	284928	3 60	33 9
15-16	2.33	13 8	30012	1.20	3.77	¼	27.9	141.0	315840	3.86	39.1
1 in.	2.65	15.7	35168	1.27	4.27	½	32.4	163.6	366464	4.12	44.4
1-16	2.99	16.8	37632	1.35	4.77	¾	37.2	187.7	420448	4.41	51.0
⅛	3.35	18 9	42336	1.42	5.28	4.	42.3	213.6	478464	4.70	57.8
3-16	3.73	21.1	47264	1.49	5.81	¼	47 8	227.0	508480	4.98	65.2
¼	4.13	23.3	52192	1.55	6.39	½	53.6	254.5	570080	5.25	72.9
5-16	4.56	25.7	57568	1.64	7.04	¾	59.7	283.5	635040	5.53	80.5
⅜	5.00	28.2	63168	1.72	7.74	5.	66.1	314.2	703808	5.80	88.1
7-16	5.47	30.8	68992	1.80	8.48	¼	72.9	324.7	727328	6.08	97.0
½	5.95	33.6	75264	1.87	9.20	½	80.0	356.4	798336	6.36	106.
9-16	6.46	36.4	81536	1.94	9 88	¾	87.5	389.5	872480	6.63	116.
⅝	6.99	39.4	88256	2.00	10 6	6.	95.2	424 1	949984	6.90	126.
11-16	7.53	42.5	95200	2.07	11.3						

GALVANIZED IRON.

WEIGHTS PER SQUARE FOOT.

No. by Birmingham wire gauge.	Thickness in inches.	Flat. Lbs.	Corrugated. Lbs.	Corrugated on roof Lbs.	No. by Birmingham wire gauge.	Thickness in inches.	Flat. Lbs.	Corrugated. Lbs.	Corrugated on roof Lbs.
30	.012	.806	.896	1.08	21	.032	1.63	1.81	2.17
29	.013	.857	.952	1.14	20	.035	1.75	1.94	2.33
28	.014	.897	.997	1 20	19	042	2.03	2.26	2.71
27	.016	.978	1 09	1.30	18	.049	2.32	2 58	3.09
26	.018	1.06	1.18	1.41	17	.058	2.68	2 98	3.57
25	.020	1.14	1.27	1.52	16	.065	2.96	3.29	3 95
24	.022	1.22	1.36	1.62	15	.072	3.25	3 61	4.33
23	.025	1.34	1.49	1.79	14	.083	3.69	4.10	4.92
22	028	1.46	1.62	1.95	13	.095	4.18	4.64	5.57

The Corrugations are 5 inches wide from centre to centre, and 1 inch deep.

When laid on roof it laps on sides 2½ inches and 4 inches on ends.

PLATE IRON WASHERS.

STANDARD SIZES.

Diameters. Washer	Diameters. Bolt hole	Thickness Birmg. Wire Gauge.	Number of Washers p. pound	Diameters. W'sher	Diameters. Bolt hole.	Thickness Birmg. Wire Gauge.	Number of Washers pr. pound
Inches.	Inches.			Inches.			
½	¼	18	543	1¾	11/16	10	17.0
⅝	5/16	16	228	2	13/16	10	10 7
¾	5/16	16	147	2¼	15/16	9	8.7
⅞	⅜	16	123	2½	1 1/16	9	6.3
1	7/16	14	70	2¾	1¼	9	4.7
1¼	½	14	50	3	1⅜	9	3.7
1⅜	9/16	12	30	3½	1½	9	3.0
1½	⅝	12	257				

Weight of heads and nuts of iron bolts.—The weights include both a head and a nut, which are supposed to be neatly finished off. Rough machine-made ones frequently weigh from ¼ to ⅓ more.

Diameter of bolt in inches.	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2½	3
Weight of an hexagonal head and nut in lbs.	.017	.057	.128	.267	.43	.73	1.10	2.14	3.78	5.6	8.75	17.	28.8
Weight of a square head and nut in lbs.	.021	.069	.164	.320	.55	.88	1.31	2.56	4.42	7.0	10.5	21.	36.4

TO COMPUTE THE WEIGHT OF WROUGHT AND CAST IRON BOLTS. (Allen).

Wrought Iron Bolts, square the radius of the bolt, and multiply by 10; the product is the weight, in pounds, per foot.

For Cast Iron Bolts or Rods, multiply the product by .926.

TABLE OF HEXAGON NUTS AND BOLT HEADS.

Diam. of Bolt in Inches.	Width of Nut over angles.	Width of Nut over sides.	Thickness of Head.	Thickness of Nut.	Diam. of Bolt in Inches.	Width of Nut over angles.	Width of Nut over sides.	Thickness of Head.	Thickness of Nut.
¼	7-16	⅜	¼	¼	1¼	2⅛	1⅞	1	1¼
5-16	⅝	9-16	5-16	5-16	1⅜	2⅜	2	1	1⅜
⅜	⅝	9-16	5-16	⅜	1½	2⅝	2¼	1⅛	1½
7-16	⅞	¾	7-16	7-16	1⅝	2⅞	2½	1¼	1⅝
½	⅞	¾	7-16	½	1¾	3	2⅝	1⅜	1¾
9-16	1	⅞	½	9-16	1⅞	3¼	2¾	1½	1⅞
⅝	1⅛	1	½	⅝	2	3½	3	1⅝	2
¾	1⅜	1 3-16	⅝	¾	2¼	3⅞	3⅜	1¾	2¼
⅞	1½	1 5-16	¾	⅞	2½	4⅜	3¾	2	2½
1	1¾	1½	⅞	1	2¾	4¾	4⅛	2¼	2½
1⅛	1⅞	1⅝	⅞	1⅛	3	5¼	4½	2½	3

NUMBER OF COLD PUNCHED NUTS PER 100 LBS

	Square.	Hexagon.		Square.	Hexagon.
⅜-in.	1951	3020	1-in.	109	100
½ "	812	800	1⅛ "	81	83
⅝ "	428	444	1¼ "	65	62
¾ "	248	261	1½ "	34	31
⅞ "	165	165			

NUMBER OF HOT PRESSED NUTS PER 100 LBS.

	Square.	Hexagon.		Square.	Hexagon.
½-in.	1100	1250	1-in.	150	170
⅝ "	550	650	1⅛ "	98	110
¾ "	375	415	1¼ "	70	80
⅞ "	230	255	1½ "	45	55

WEIGHT of 100 BOLTS with SQUARE HEADS and NUTS

Length under Head.	Diameter of Bolts.						
	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.	⅞ in.	1 in
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	3½	9	20	32	....	....	....
1¼	3⅞	9⅞	21	34½	....	....	....
1½	4¼	10¾	22	37	....	....	....
1¾	4⅝	11⅝	23	39½	....	....	....
2	5	12½	24	42	70	130	180
2¼	5⅜	13⅛	25½	44½	73½	132½	185
2½	5¾	14⅜	27	47	77	135	190
2¾	6⅛	15½	28½	49½	80½	137½	195
3	6½	16¼	30	52	84	140	200
3½	7⅛	18⅛	33	56½	90	148	210
4	7¾	20	36	61	96	156	220
4½	8⅜	21⅝	39	65½	101½	164	230
5	9	23¼	42	70	107	172	240
5½	9¾	24⅞	45	74	112½	180	251
6	10⅜	26½	48	78	118	188	262
7	11¾	29½	54	86	130	204	284
8	13⅛	33	60	94	143	220	306
9	14½	36	66	102	156	236	328
10	16	40	72	110	170	252	350
11	17¼	43	78	118	185	268	372
12	18⅝	46	84	127	200	284	393

WEIGHT of 100 BOLTS with HEXAGON HEADS and NUTS.

Length under Head.	Diameter of Bolts.						
	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	3⅛	7¾	16⅜	26¾	....	....	....
1¼	3½	8⅝	17⅜	29¼	....	....	....
1½	3⅞	9½	18⅜	31¾	....	....	....
1¾	4¼	10⅜	19⅜	34¼	....	....	....
2	4⅝	11¼	20⅜	36¾	58	115	159
2¼	5	12¼	21⅞	39¼	61½	117½	164
2½	5⅜	13⅛	23⅜	41¾	65	120	169
2¾	5¾	14	24⅞	44¼	68½	122½	174
3	6⅛	15	26⅜	46¾	72	125	179
3½	6¾	16⅞	29⅜	51¼	78	133	189
4	7⅜	18⅞	32⅜	55¾	84	141	199
4½	8	20⅜	35⅜	60¼	89½	149	209
5	8⅝	22	38⅜	64¾	95	157	219
5½	9⅜	23⅝	41⅜	68¾	100½	165	230
6	10	25¼	44⅜	72¾	106	173	241
7	11⅜	28¼	50⅜	80¾	118	189	263
8	12¾	31¾	56⅜	88¾	131	205	285
9	14⅛	34¾	62⅜	96¾	144	221	307
10	15⅝	38¾	68⅜	104¾	158	237	329
11	16⅞	41⅜	74⅜	112⅞	173	253	351
12	18¼	44¾	80⅜	121½	188	269	372

SCREWS.

American Standard Screw Threads,

As recommended by a Committee of the Franklin Institute.

Adopted by the Master-Car Builder's Association, June 15th, 1871.

Diam. of Screw.	Thre'ds per Inch.	Diameter at Root of Thread.	Width of Flat.	Diam. of Screw.	Threads per Inch.	Diameter at Root of Thread.	Width of Flat.
1-4	20	.185	.0062	2¼	4½	1.962	.0277
5-16	18	.240	.0074	2½	4	2.176	.0312
3-8	16	.294	.0078	2¾	4	2.426	.0312
7-16	14	.344	.0089				
1-2	13	.400	.0096	3	3½	2.629	.0357
9-16	12	.454	.0104	3¼	3½	2.878	.0357
5-8	11	.507	.0113	3½	3½	3.100	.0384
3-4	10	.620	.0125	3¾	3	3.317	.0413
7-8	9	.731	.0138				
				4	3	3.567	.0413
1	8	.837	.0156	4¼	2⅞	3.798	.0435
1⅛	7	.940	.0178	4½	2¾	4 028	.0454
1¼	7	1.065	.0178	4¾	2⅝	4.256	.0476
1⅜	6	1.160	.0208				
1½	6	1.284	.0208	5	2½	4.480	.0500
1⅝	5½	1.389	.0227	5¼	2½	4.730	.0500
1¾	5	1.491	.0250	5½	2⅜	4.953	.0526
1⅞	5	1.616	.0250	5¾	2⅜	5.203	.0526
2	4½	1.712	.0277	6	2¼	5.423	.0555

TABLE OF WITWORTH'S SCREWS.

(Angular Threads.)

Diam. in Inches.	No. of Threads to Inch.	Diam. in Inches.	No. of Threads to Inch.	Diam. in Inches.	No. of Threads to Inch.	Diam. in Inches.	No. of Threads to Inch.
3-16	24	1	8	2¼	4	4½	2⅞
¼	20	1⅛	7	2½	4	4¾	2¾
5-16	18	1¼	7	2¾	3½	5	2¾
⅜	16	1⅜	6	3	3½	5¼	2⅝
7-16	14	1½	6	3¼	3¼	5½	2⅝
½	12	1⅝	5	3½	3¼	5¾	2½
⅝	11	1¾	5	3¾	3	6	2½
¾	10	1⅞	4½	4	3		
⅞	9	2	4½	4½	2⅞		

Angle of threads = 55°.

Depth of threads = pitch of screws.

1-6 of depth is rounded off at top and bottom.

No. of threads to the inch in square threads = ½ number of those in angular threads.

WEIGHT OF BALLS.

Diam. in Inches.	Cast Lead.	Cast Copper.	Cast Brass.	Cast Iron.	Diam. in Inches.	Cast Lead.	Cast Copper	Cast Brass.	Cast Iron.
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
½	.026	.021	.019	.017	5¼	30.1	24.1	21.5	19.8
¾	.088	.070	.063	.058	½	34.7	27.7	24.7	22.7
1.	.209	.167	.148	.136	¾	39.6	31.7	28.3	25.9
¼	.408	.325	.290	.266	6	45.0	36.0	32.0	29.4
½	.705	.562	.501	.460	½	57.2	45.8	40.8	37.4
¾	1.12	.893	.795	.731	7	71.5	57.2	50.9	46.8
2.	1.67	1.33	1.19	1.07	½	88.0	70.3	62.6	57.5
¼	2.38	1.90	1.69	1.55	8.	106.	85.3	76.0	69.8
½	3.25	2.60	2.32	2.13	½	127.	102.	91.2	83.7
¾	4.34	3.47	3.09	2.83	9.	151.	121.	108.	99.4
3.	5.63	4.50	4.01	3.68	½	178.	143.	127.	117.
¼	7.15	5.72	5.10	4.68	10	208.	167.	148.	136.
½	8.94	7.14	6.36	5.85	½	241.	193.	172.	158.
¾	11.0	8.79	7.83	7.19	11.	277.	222.	198.	182.
4.	13.4	10.7	9.50	8.73	½	317.	253.	226.	207.
¼	16.0	12.8	11.4	10.5	12.	360	288.	257.	236.
½	18.9	15.2	13.5	12.4					
¾	22.7	17.9	15.9	14.6					
5.	26.0	20.8	18.6	17.0					

The weights of balls are as the cubes of their diams.

WEIGHT AND STRENGTH OF IRON CHAINS.

The links of ordinary iron chains are usually made as short as is consistent with easy play, in order that they may not become bent when wound around drums, sheaves, &c.; and that they may be more easily handled in slinging large blocks of stone, &c. As a thick bar of iron will not sustain as heavy a load in proportion as a thinner one, so of course stout chains are proportionably weaker than slighter ones. In the following table, 20 tons *per sq. inch*, is assumed as the average breaking strain of a single straight bar of ordinary rolled iron, 1 inch in diam.; or 1 inch square; 19 tons, from 1 to 2 inches; and 18 tons, from 2 to 3 inches.

TABLE OF STRENGTH OF CHAINS.—(Trautwine.)

Diam. of rod of which links are made.	Weight of chain per ft. run.	Breaking strain of the chain.		Diam. of rod of which links are made.	Weight of chain per ft. run.	Breaking strain of the chain.	
Ins.	Lbs.	Lbs.	Tons.	Ins.	Lbs.	Lbs.	Tons.
3–16	.325	1731	.773	1	9.26	49280	22.00
¼	.579	3069	1.37	1⅛	11.7	59226	26.44
5–16	.904	4794	2.14	1¼	14.5	73114	32.64
⅜	1.30	6922	3.09	1⅜	17.5	88301	39.42
7–16	1.78	9408	4.20	1½	20.8	105280	47.00
½	2.31	12320	5.50	1⅝	24.4	123514	55.14
9–16	2.93	15590	6.96	1¾	28.4	143293	63.97
⅝	3.62	19219	8.58	1⅞	32.6	164505	73.44
11–16	4.38	23274	10.39	2	37.0	187152	83.55
¾	5.21	27687	12.36	2¼	46.9	224448	100.2
13–16	6.11	32301	14.42	2½	57.9	277088	123.7
⅞	7.10	37632	16.80	2¾	70.0	335328	149.7
15–16	8.14	43277	19.32	3	83.3	398944	178.1

NOTES ON THE USES OF WIRE ROPE.

BY JOHN ROEBLING'S SONS & CO., TRENTON, N. J.

Two kinds of Wire Rope are manufactured. The most pliable variety contains 19 wires in the strand, and is generally used for hoisting and running rope. The ropes with 12 wires and 7 wires in the strand are stiffer, and are better adapted for standing rope, guys and rigging.

For safe working load, allow one-fifth to one-seventh of the ultimate strength, according to speed, so as to get good wear from the rope. When substituting wire rope for hemp rope, it is good economy to allow for the former the same weight per foot which experience has approved for the latter.

Wire Rope is as pliable as new hemp rope of the same strength; the former will therefore run over the same sized sheaves and pulleys as the latter. But the greater the diameter of the sheaves, pulleys or drums, the longer wire rope will last. In the construction of machinery for wire rope, it will be found good economy to make the drums and sheaves as large as possible.

Experience has demonstrated that the wear increases with the speed. It is therefore better to increase the load than the speed.

Wire rope is manufactured either with a wire or a hemp centre. The latter is more pliable than the former, and will wear better where there is short bending.

Wire rope must not be coiled or uncoiled like hemp rope. When mounted on a reel, the latter should be mounted on a spindle or flat turn-table to pay off the rope. When forwarded in a small coil without reel, roll it over the ground like a wheel, and run off the rope in that way. All untwisting or kinking must be avoided.

To preserve wire rope, apply raw linseed oil with a piece of sheep-skin, wool inside; or mix the oil with equal parts of Spanish brown or lamp-black.

To preserve wire rope under water or under ground, take mineral or vegetable tar, and add 1 bushel of fresh slacked lime to 1 barrel of tar, which will neutralize the acid. Boil it well, and saturate the rope with the hot tar. To give the mixture body, add some sawdust.

In no case should *galvanized rope* be used for running rope. One day's use scrapes off the coating of zinc, and rusting proceeds with twice the rapidity.

The grooves of cast-iron pulleys and sheaves should be filled with well seasoned blocks of hard wood set on end, to be renewed when worn out. This end wood will save wear and increase adhesion. The smaller pulleys or rollers which support the ropes on inclined planes, should be construced on the same plan. When large sheaves run with very great velocity, the grooves should be lined with leather, set on end, or with India rubber. This is done in the case of all sheaves used in the *transmission of power* between distant points by means of rope, which frequently runs at the rate of 4,000 feet per minute.

Steel ropes are, to a certain extent, taking the place of iron ropes, where it is a special object to combine lightness with strength.

But in substituting a steel rope for an iron running rope, the object in view should be to gain an increased wear from the rope rather than to reduce the size.

STANDARD HOISTING ROPES WITH 19 WIRES TO THE STRAND.

IRON.

Trade No.	Circumference in inches.	Diameter.	Weight per foot in lbs. of Rope with Hemp Centre.	Breaking strain in tons of 2,000 lbs.	Proper working load in tons of 2,000 lbs.	Circumference of Hemp Rope of equal strength.	Min. size of drum or sheave in feet.
1	6¾	2¼	8.00	74	15	15½	8
2	6	2	6.30	65	13	14½	7
3	5½	1¾	5.25	54	11	13	6½
4	5	1⅝	4.10	44	9	12	5
5	4¾	1½	3.65	39	8	11½	4¾
5½	4⅜	1⅜	3.00	33	6½	10¼	4½
6	4	1¼	2.50	27	5½	9½	4
7	3½	1⅛	2.00	20	4	8	3½
8	3⅛	1	1.58	16	3	7	3
9	2¾	⅞	1.20	11½	2½	6	2¾
10	2¼	¾	0.88	8.64	1¾	5	2½
10¼	2	⅝	0.70	5.13	1¼	4½	2
10½	1⅝	9-16	0.44	4.27	¾	4	1¾
10¾	1½	½	0.35	3.48	½	3½	1½

CAST STEEL.

Trade No.	Circumference in inches.	Diameter.	Weight per foot in lbs. of Rope with Hemp Centre.	Breaking strain in tons of 2,000 lbs.	Proper working load in tons of 2,000 lbs.	Circumference of Hemp Rope of equal strength.	Min size of drum or sheave in feet.
1	6¾	2¼	8.00	130	26		9
2	6	2	6.30	100	21		8
3	5½	1¾	5.25	78	17	15¾	7½
4	5	1⅝	4.10	64	13	14½	6
5	4¾	1½	3.65	55	11	13½	5½
6	4	1¼	2.50	39	8	11½	5
7	3½	1⅛	2.00	30	6	10	4½
8	3⅛	1	1.58	24	5	9¼	4
9	2¾	⅞	1.20	20	4	8	3¾
10	2¼	¾	0.88	13	3	6½	3½
10¼	2	⅝	0.70	9	2	5¼	3
10½	1⅝	9-16	0.44	6½	1½	4¾	2¾
10¾	1½	½	0.35	5½	1	4½	2

NOTE.—The weight of Wire Centre Ropes is 10 per cent. more than that of Ropes with Hemp Centre.

TRANSMISSION AND STANDING ROPES WITH 7 WIRES TO THE STRAND.

IRON.

Trade No.	Circumference.	Diameter.	Weight per foot in lbs. of Rope with Hemp Cen.	Breaking strain in tons of 2000 pounds.	Proper working Load in tons of 2000 pounds.	Circumference of Hemp Rope of equal strength.
11	4⅝	1½	3.37	36	9	10¾
12	4¼	1⅜	2.77	30	7½	10
13	3¾	1¼	2.28	25	6¼	9¼
14	3⅜	1⅛	1 82	20	5	8
15	3	1	1.50	16	4	7
16	2⅝	⅞	1.12	12.3	3	6¼
17	2⅜	¾	0.88	8.8	2¼	5¾
18	2⅛	11-16	0.70	7.6	2	5
19	1⅞	⅝	0.57	5.8	1½	4¾
20	1⅝	9-16	0.41	4.1	1	4
21	1⅜	½	0.31	2.83	¾	3¼
22	1¼	7-16	0.23	2 13	½	2¾
23	1⅛	⅜	0.19	1.65		2½
24	1	5-16	0.16	1 38		2¼
25	⅞	9-32	0.125	1.03		2

CAST STEEL.

Trade No.	Circumference.	Diameter.	Weight per foot in lbs. of Rope with Hemp Cen.	Breaking strain in tons of 2000 pounds.	Proper working Load in tons of 2000 pounds.	Circumference of Hemp Rope of equal strength.
11	4⅝	1½	3.37	67	16	15
12	4¼	1⅜	2.77	55	12½	13
13	3¾	1¼	2 28	45	10	12
14	3⅜	1⅛	1.82	36	8	10¾
15	3	1	1.50	30	6½	10
16	2⅝	⅞	1.12	22	5	8½
17	2⅜	¾	0.88	17	3½	7¼
18	2⅛	11-16	0 70	13½	3	6½
19	1⅞	⅝	0.57	10	2¼	5½
20	1⅝	9-16	0.41	8	1¾	5
21	1⅜	½	0.31	6	1¼	4¾
23	1⅛	⅜	0.19	4	1	3¾
24	1	5-16	0.16	3	¾	3¼

NOTE.—The weight of Wire Centre Ropes is 10 per cent. more than that of Ropes with Hemp Centres.

STRAIN ON HOISTING CHAINS AND CABLES ON INCLINED PLANES.

Rise per 100 feet Horizont'l	Angle of Inclination.	Strain in lbs. per ton of 2000 lbs.	Rise per 100 feet Horizontal	Angle of Inclination.	Strain in lbs. per ton of 2000 lbs.
5	2° 52′	112	105	46° 24′	1456
10	5° 43′	211	110	47° 44′	1488
15	8° 32′	308	115	49°	1517
20	11° 19′	404	120	50° 12′	1545
25	14° 3′	497	125	51° 21′	1569
30	16° 42′	585	130	52° 26′	1592
35	19° 18′	672	135	53° 29′	1614
40	21° 49′	754	140	54° 28′	1635
45	24° 14′	832	145	55° 25′	1654
50	26° 34′	905	150	56° 19′	1671
55	28° 49′	975	155	57° 11′	1687
60	30° 58′	1039	160	58°	1702
65	33° 2′	1100	165	58° 47′	1716
70	35°	1157	170	59° 33′	1730
75	36° 53′	1210	175	60° 16′	1743
80	38° 40′	1259	180	60° 57′	1754
85	40° 22′	1304	185	61° 37′	1766
90	42°	1347	190	62° 15′	1776
95	43° 32′	1387	195	62° 52′	1785
100	45°	1422	200	63° 27′	1794

In calculating the strains on the chain, an allowance of 12 lbs. per ton has been made for the rolling friction of the load on a level. An additional allowance should be made for the weight of the chain, depending of course on its size and length. The breaking strain of the chain should be six or seven times that which it is to bear.

MANILLA ROPE.

Diam. Ins.	Circ. Ins.	Wt. per foot lbs.	Breaking load.		Diam. Ins.	Circ. Ins.	Wt per foot lbs.	Breaking load.	
			Tons.	lbs.				Tons.	lbs.
.239	¾	.019	.25	560	1.91	6	1.19	11.4	25536
.318	1	.033	.35	784	2.07	6½	1.39	13.0	29120
.477	1½	.074	.70	1568	2.23	7	1.62	14.6	32704
.636	2	.132	1.21	2733	2.39	7½	1.86	16.2	36288
.795	2½	.206	1.91	4278	2.55	8	2.11	17.8	39872
.955	3	.297	2.73	6115	2.86	9	2.67	21.0	47040
1.11	3½	.404	3.81	8534	3.18	10	3.30	24.2	54208
1.27	4	.528	5.16	11558	3.50	11	3.99	27.4	61376
1.43	4½	.668	6.60	14784	3.82	12	4.75	30.6	68544
1.59	5	.825	8.20	18368	4.14	13	5.58	33.8	75712
1.75	5½	.998	9.80	21952	4.45	14	6.47	37.0	82880

The strength of Manilla ropes, like that of bar iron, is very variable; and so with hemp ones. The above table supposes an average quality. Ropes of good *Italian* hemp are considerable stronger than Manilla; but their cost excludes them from general use. The tarring of ropes is said to lessen their strength; and when exposed to the weather, their durability also. We believe that the use of it in standing rigging is partly to diminish contraction and expansion by alternate wet and dry weather.

The strengths of pieces from the same coil may vary 25 per cent.

A few months of exposed work weakens ropes 20 to 50 per cent.

SCALE FOR TEMPERING TOOLS OF CARBON STEEL, (from Thurston, Part II, p. 326.)

MATERIAL CUT.	TOOLS URGED BY								
	PRESSURE.				IMPACT.				
	A.	B.	C.	D.	E.	F.	G.	H.	K.
Unannealed Steel . .	0	1	2	2	3	4	2	2	7
Annealed Steel . . .	1	2	2	3	3	5	3	..	..
Chilled Cast Iron . .	0	0	..	..	..	..	..	..	..
Hard Cast Iron . . .	0	2	3	3	4	2	..	..	..
Soft Cast Iron . . .	1	3	3	3	5	3	..	..	..
Gun Metal, Bronze . .	1	2	3	3	6	6	..	..	..
Yellow Brass	2	3	3	3	6	6	..	..	..
Soft Composition . . .	3	4	3	3	7	7	..	..	..
Wrought Iron	3	6	3	3	7	7	4	..	..
Copper	4	6	3	3	7	7	4	..	..
Wood	6	6	..	..	..	..	..	..	..

NOMENCLATURE.

0 To remain as dipped.
1 Light straw color.
2 Dark " "
3 Orange color.
4 Reddish purple color.
5 Purple.
6 Bluish purple.
7 Dark blue.
8 Light blue.
9 Bluish gray.
10 Soft.

A Turning or planing tools.
B Drills, bits.
C Taps, dies.
D Reamers.
E Cold chisels.
F Flogging chisels.
G Caulking tools.
H Hammers.
K Springs.

German Silver is made by English founders for small bells and similar articles, of copper 57, zinc 19, nickel 19, lead 3, tin plate 2. The copper and nickel are fused together first, the zinc added after their fusion, and the other metals last. Commercial zinc containing lead is rarely pure enough for the finer grades of this alloy which do not permit the introduction of lead. It is difficult to obtain this alloy in correct proportions and of good quality.

Babbitt Metal. This is made by melting separately 4 parts copper, 12 Banca tin, 8 regulus of antimony, and adding 12 parts of tin after fusion. The antimony is added to the first portion of tin, and the copper is introduced after taking the melting pot away from the fire, and before pouring into the mould. The charge is kept from oxidation by a surface coating of powdered charcoal, and this mixture is called "hardening."

A "lining metal" consists of this "hardening" fused with twice its weight of tin, thus making a mixture containing 3.7 parts copper, 7.4 parts antimony, and 88.9 parts tin. The bearing to be lined is cast with a shallow recess to receive the Babbitt Metal. The portion to be lined is washed with alcohol and powdered with sal amoniac, and those surfaces which are not to receive the lining metal are to be covered with a clay wash. The bearing is then warmed sufficiently to volatilize a portion of the sal amoniac, and tinned.

The lining is next poured in between an arbor or former—which takes the place of the journal—and the bearing. Founders often prefer to melt the copper first in a plumbago crucible, then to dry the zinc carefully, and immerse the whole in the barely fluid copper.

The useful alloys are exceedingly numerous, and of extraordinary variety in appearance and physical qualities.

Several pages might be filled with lists of alloys, but the following table from Haswell must suffice.

ALLOYS AND COMPOSITIONS.

	Copper.	Zinc.	Tin.	Nickel.	Lead.	Antimony.	Bismuth.	Silver.	Cobalt of Iron.	Iron.	Arsenic.
Argentan..........	55.	24.	—	21.	—	—	—	—	—	—	—
Argentiferous......	50.	2 5	2.5	40.	2.5	—	—	—	—	2 5	—
Babbitt's metal....	3.7	—	89.	—	—	7.3	—	—	—	—	—
Brass, common	84.3	5.2	10.5	—	—	—	—	—	—	—	—
" "	75.	25.	—	—	—	—	—	—	—	—	—
" " hard	79 3	6.4	14.3	—	—	—	—	—	—	—	—
" Mathematical instruments..	92.2	—	7.8	—	—	—	—	—	—	—	—
" pinchbeck. ...	80.	20.	—	—	—	—	—	—	—	—	—
" red tombac...	88.8	11 2	—	—	—	—	—	—	—	—	—
" rolled	74.3	22.3	3.4	—	—	—	—	—	—	—	—
" tutenag.......	50	31.	—	19.	—	—	—	—	—	—	—
" very tenacious	88.9	2 8	8.3	—	—	—	—	—	—	—	—
" wheels, valves	90.	—	10.	—	—	—	—	—	—	—	—
" white.........	10.	80.	10	—	—	—	—	—	—	—	—
" wire	67.	33.	—	—	—	—	—	—	—	—	—
" yellow, fine...	66.	34.	—	—	—	—	—	—	—	—	—
Britannia metal....	—	—	25.	—	—	25.	—	—	—	—	—
When fused, add	—	—	—	—	—	25.	25.	—	—	—	—
Bronze, red........	87.	13.	—	—	—	—	—	—	—	—	—
" red........	86.	11 1	2.9	—	—	—	—	—	—	—	—
" yellow	67 2	31.2	1.6	—	—	—	—	—	—	—	—
" Cymbals ..	80.	—	20.	—	—	—	—	—	—	—	—
" gun metal, lge.	90.	—	10.	—	—	—	—	—	—	—	—
" " small	93.	—	7	—	—	—	—	—	—	—	—
" Medals....	93.	—	7.	—	—	—	—	—	—	—	—
" Statuary...	91.4	5.5	1.4	—	1 7	—	—	—	—	—	—
Chinese silver......	65.1	19 3.	—	13.	—	—	—	2 48	12.	—	—
" white copper	40.4	25.4	2.6	31.6	—	—	—	—	—	—	—
Church bells	80.	5.6	10.1	—	4 3	—	—	—	—	—	—
"	69.	—	31.	—	-	—	—	—	—	—	—
Clock bells.........	72.	—	26 5	—	—	—	—	—	—	1.5	—
Clocks, Musical bells	87.5	—	12.5	—	—	—	—	—	—	—	—
German silver......	33.3	33 4	—	33.3	—	—	—	—	—	—	—
" "	40.4	25.4	—	31.6	—	—	—	—	—	2 6	—
" " fine...	49.5	24.	—	24.	—	—	—	—	—	2.5	—
Gongs..............	81.6	—	18.4	—	—	—	—	—	—	—	—
House bells........	77.	—	23.	—	—	—	—	—	—	—	—
Lathe bushes........	80.	—	20.	—	—	—	—	—	—	—	—
Machinery bearings	87.5	—	12.5	—	—	—	—	—	—	—	—
" " hard	77.4	7.	15 6	—	—	—	—	—	—	—	—
Metal that expands in cooling........	—	—	—	—	75.	16 7	8 3	—	—	—	—
Muntz metal........	60.	40.	—	—	—	—	—	—	—	—	—
Pewter, best........	—	—	86.	—	—	14	—	—	—	—	—
"	—	—	80.	—	20.	—	—	—	—	—	—
Printing characters.	—	—	—	—	80.	20.	—	—	—	—	—
Sheathing metal....	56.	45.	—	—	—	—	—	—	—	—	—
Speculum "	66.	—	22.	—	—	—	—	—	—	—	12.
" "	50.	21.	29.	—	—	—	—	—	—	—	—
Telescopic mirrors..	66.6	—	33.4	—	—	—	—	—	—	—	—
Temper†	33.4	—	66.6	—	—	—	—	—	—	—	—
Type and stereotype plates...........	—	—	—	—	69.	15.5	15 5	—	—	—	—
White metal........	7.4	7.4	28 4	—	—	56.8	—	—	—	—	—
" " hard....	69.8	25.8	4.4	—	—	—	—	—	—	—	—
Oreide..............	73.	12 3	Magnesia.... 4.4; Sal-ammoniac 2.5				Cream of tartar 6 5; Quick-lime ... 1.2				

† For adding small quantities of copper.

SOLDERS.

	Copper.	Tin.	Lead.	Zinc.	Silver.	Bismuth.	Gold.	Calcimine.	Antimony.
Tin...........	—	25	75	—	—	—	—	—	—
"	—	58	16	—	—	16	—	—	10
" coarse, melts at 500°.	—	33	67	—	—	—	—	—	—
Tin, ordinary, melts at 360°	—	67	33	—	—	—	—	—	—
Spelter, soft....	50	—	—	50	—	—	—	—	—
" hard..	67	—	—	33	—	—	—	—	—
Lead..........	—	33	67	—	—	—	—	—	—
Steel..........	13	—	—	5	82	—	—	—	—
Brass or Copper	50	—	—	50	—	—	—	—	—
Fine Brass	47	—	—	47	6	—	—	—	—
Pew'ers' or Soft	—	33	45	—	—	22	—	—	—
" "	—	50	25	—	—	25	—	—	—
Gold...........	4	—	—	—	7	—	89	—	—
" hard......	66	—	—	34	—	—	—	—	—
" soft.......	—	66	34	—	—	—	—	—	—
Silver, hard....	20	—	—	—	80	—	—	—	—
" soft......	12	—	—	—	67	—	—	21	—
Pewter.........	—	40	20	—	—	40	—	—	—
Iron...........	66	—	—	33	—	—	—	—	1
Copper.........	53	47	—	—	—	—	—	—	—

A Plastic Metallic Alloy.—See Journal of Franklin Institute, vol.. xxxix., page 55, for its composition and manufacture.

COMPOSITION FOR WELDING CAST STEEL.

Borax, 10 parts; Sal-ammoniac 1 part. Grind or pound them roughly together; fuse them in a metal pot over a clear fire, continuing the heat until all spume has disappeared from the surface. When the liquid is clear, pour the composition out to cool and concrete, and grind to a fine powder; then it is ready for use.

To use this composition, the steel to be welded should be raised to a bright yellow heat; then dip it in the welding powder, and again raise it to a like heat as before; it is then ready to be submitted to the hammer.

FUSIBLE COMPOUNDS.

Compounds.	Zinc.	Tin.	Lead.	Bismuth.	Cadmium
Rose's, fusing at 200°..........	—	25	25	50	—
Fusing at less than 200°......	33.3	—	33.3	33.4	—
Newtons', fus'g at less than 212°	—	19	31	50	—
Fusing at 150° to 160°........	—	12	25	50	13

VELOCITY AND FORCE OF THE WIND.

Description.	Miles per hour.	Feet per minute.	Feet per second.	Force in lbs. per sq. foot.
Hardly perceptible	1	88	1.47	.005
Just perceptible	2	176	2.93	.020
	3	264	4 40	.044
Gentle breeze	4	352	5 87	.079
	5	440	7.33	.123
Pleasant breeze	10	880	14 67	.492
	15	1320	22.0	1.107
Brisk gale	20	1760	29.3	1.968
	25	2200	36.6	3.075
High wind	30	2640	44.0	4 428
	35	3080	51.3	6.027
Very high wind	40	3520	58.6	7.872
	45	3960	66.0	9.963
Storm	50	4400	73 3	12.300
Great storm	60	5280	88.0	17.712
	70	6160	102 7	24.108
Hurricane	80	7040	117.3	31 488
	100	8800	146.6	49.200

PART II.

HYDRODYNAMICS.

The Properties of Water.

(CONDENSED FROM CHAPTER I OF SMITH'S HYDRAULICS.)

Water is compressible and is perfectly elastic, but the change is so minute as to have no practical consequence. Elaborate and accurate experiments have established the proposition, that the loss of head due to friction, cross currents, etc., as the water passes through a pipe, is not appreciably affected by the amount of pressure to which the interior walls of the pipe are subjected.

Pressure of Water. (D. K. Clark.)

A pressure of one lb. per sq. in. is exerted by a column of water 2.3093 feet or 27.71 inches high at 62° F; and a pressure of one atmosphere, or 14.7 lbs. per sq. in. is exerted by a column of water 33.947 feet high, or 10.347 meters at 62° F.

A column of water at 62° F. one foot high presses on the base with a force of 0.433 lbs. per square inch. A colum 100 feet high produces, therefore, a pressure on the base of 43.3 lbs. per sq. in.

Ice and Snow. (D. K. Clark.)

One cu. ft of ice at 32° weighs 57.50, and therefore floats in water at any ordinary temperature. One pound of ice has a volume of .0174 cu. ft.

Water expands in passing into the solid state about 8.5 per cent. of the volume of the water. One cu. ft. of fresh snow weighs 5.2 lbs. Snow has 12 times the bulk of water, and its specific gravity is .0833.

Impurities.

Perfectly pure water is not palatable, and it is the business of the chemist to distinguish between those sub-

stances and those amounts of certain substances, some of which render water unfit for domestic use, while some render it safely potable.

Amateurs in chemistry are not safe guides, either in the methods of water analysis or of the interpretation of results, and the best authorities agree that chemical analysis *alone*, can do no more than indicate the probabilities, when questions arise as to the fitness of any water for domestic use. Gross pollution may be quite easily detected, but the dangerous border line between health and disease is not always easily established.

Unfortunately perhaps, a water unfit for drinking by reason of contamination, may be clear, cool, bright and sparkling, and have no unpleasant taste.

A well in a thickly settled community should always be regarded with suspicion, and even an isolated farm house *may* have its highly valued well poisoned by means of some unsuspected underground connection with a barn cellar, a privy vault or a cesspool. When a well is pure and free from contamination, there is no water equal to that offered by the old oaken bucket.

The biological examination of water has recently become an important and valuable process for the determination of its purity.

HAMILTON SMITH says, "Thick oil passing through an orifice has a much larger coefficient of discharge than water; hence it is probable that water carrying in suspension a very large quantity of clayey sediment, will have a slightly larger coëfficient of discharge than pure water, either through an orifice or over a weir.

For conduits and pipes, it is most probable that for very small values of r (hydraulic mean radius) or very low velocities, muddy water will flow with a slower velocity than clear water; the increased viscosity of the water, due to the sediment in suspension, will in all probability, with such small values of r and v, appreciably retard the flow."

The following table of the weight of water at different temperatures, is from HAMILTON SMITH, who says, "that the table is based upon experiments made by Rossetti, Kopp and others, and embodies the most accurate determinations thus far made upon the density of water with various temperatures."

TABLE OF WEIGHT OF 1 CUBIC FOOT OF DISTILLED WATER.

Temp.	Weight.	Temp.	Weight.	Temp.	Weight.	Temp.	Weight.
32	62.416	78	62.235	123	61.671	168	60.842
33	62.418	79	62.227	124	61.655	169	60.821
34	62.420	80	62.217	125	61.638	170	60.799
35	62.421	81	62.208	126	61.621	171	60.778
36	62.422	82	62.199	127	61.605	172	60.757
37	62.423	83	62.189	128	61.588	173	60.736
38	62.423	84	62.179	129	61.571	174	60.715
39.3	62.424	85	62.169	130	61.555	175	60.694
40	62.423	86	62.159	131	61.539	176	60.672
41	62.423	87	62.149	132	61.523	177	60.651
42	62.423	88	62.139	133	61.506	178	60.629
43	62.422	89	62.129	134	61.490	179	60.608
44	62.420	90	62.118	135	61.473	180	60.586
45	62.419	91	62.107	136	61.456	181	60.565
46	62.418	92	62.096	137	61.439	182	60.543
47	62.416	93	62.084	138	61.422	183	60.520
48	62.413	94	62.073	139	61.404	184	60.498
49	62.411	95	62.061	140	61.386	185	60.476
50	62.408	96	62.049	141	61.368	186	60.453
51	62.405	97	62.036	142	61.350	187	60.431
52	62.402	98	62.024	143	61.332	188	60.409
53	62.398	99	62.011	144	61.314	189	60.387
54	62.394	100	61.998	145	61.296	190	60.365
55	62.390	101	61.986	146	61.278	191	60.342
56	62.386	102	61.973	147	61.259	192	60.320
57	62.381	103	61.960	148	61.241	193	60.297
58	62.377	104	61.947	149	61.222	194	60.274
59	62.372	105	61.933	150	61.203	195	60.251
60	62.366	106	61.920	151	61.184	196	60.228
61	62.360	107	61.907	152	61.165	197	60.205
62	62.355	108	61.893	153	61.146	198	60.182
63	62.349	109	61.879	154	61.126	199	60.159
64	62.342	110	61.865	155	61.106	200	60.135
65	62.336	111	61.851	156	61.086	201	60.111
66	62.329	112	61.837	157	61.067	202	60.088
67	62.322	113	61.823	158	61.047	203	60.064
68	62.315	114	61.809	159	61.027	204	60.040
69	62.308	115	61.794	160	61.006	205	60.015
70	62.300	116	61.780	161	60.986	206	59.991
71	62.293	117	61.765	162	60.966	207	59.966
72	62.285	118	61.750	163	60.945	208	59.942
73	62.277	119	61.734	164	60.925	209	59.917
74	62.269	120	61.719	165	60.904	210	59.893
75	62.261	121	61.703	166	60.883	211	59.868
76	62.253	122	61.687	167	60.862	212	59.843
77	62.244						

For weight of water not distilled, see Part III, Boilers.

Rossetti considers that the most probable temperature of maximum density is about 4.107° C or 39.33 F.

The density of water below freezing point was determined by taking advantage of the remarkable property of water of remaining unfrozen when kept perfectly quiet, while the temperature is being reduced from above the freezing point to —10° Cent.

Rainfall.

Mr. Desmond FitzGerald, in a paper read before the New England Water Works Association (Proc. Vol. 1, No. 1,) said:

In the Gulf and Gulf Stream we have an immense mass of very warm water (80°). From this mass of warm water there must be an enormous evaporation, and this is the great source from which we get our mean rainfall.

There is a small district along the coast which receives a slight increase from the Atlantic Ocean. When you get beyond the Mississippi it is pretty dry, because the rainfall coming from the warm Pacific currents, has been condensed against the tops of the mountain ranges, and the clouds almost entirely robbed of their moisture.

The mean of some thirty years of observation upon the rainfall of Boston gives us yearly about 48 inches. * * * * If we examine a profile of the different years, we shall find a great variety in the amounts, running in a general way from thirty to sixty inches. The irregularity in the outline does not suggest any particular law of increase or decrease; in fact, our periods are rather too short for this purpose. * * * *

Mr. FitzGerald gives 28 inches as the minimum annual rainfall for the vicinity of Boston.

Mr. Trautwine gives the following table of annual rainfall in inches, but says that "it is highly probable that most of the results are merely approximate."

Augusta, Ga.	23	Fort Preble, Me.	45¼
Albany, N. Y.	31 to 51	Fort Constitution, N. H.	35½
Arkansas	41	Fort Adams, R. I.	52½
Bath, Me.	30 to 50	Ft. Hamilton, N.Y. Harbor	43⅔
Baltimore, Md.	40	Fort Niagara, N. Y.	31¾
Boston, Mass.	25 to 46	Fort Monroe, Va.	51
Charleston, S. C.	40 to 76?	Fort Kearney. Neb.	28
Canada	36	Fort Laramie, Neb.	20
Carlisle, Penn.	34	Fort Worth, Tex.	41
Detroit, Mich.	30	Fort McIntosh. Tex.	18⅔
Frankford, Penn.	33 to 54	Fort Dallas, Ore.	14⅓
Fort Gaston, Cal. in 9 mos.	129	Key West, Fla.	30 to 39
Fort Yuma, Cal.	3¼	Lebanon, Penn.	34 to 45
Port Oxford, Ore.	69	Michigan	35

Fort Pike, La.	72	Monterey, Cal.	12¼
Fort Pierce. E. Fla.	63	Marietta, Ohio	35 to 54
Fort Conrad. New Mex.	6¼	New Orleans, La.	51
Fort Kent, Me.	36½	New Fane, Vt.	36 to 74?
New England, average	47	Natchez, Miss., av.	37 to 58
New York State "	36¼	Ohio, average	36
Phila. Penn. "	34 to 61	Phila. av. for 54 yrs. to 1884	45.2
Pennsylvania "	41	Savannah, Ga. average	30 to 60
Stow, Mass. "	33 to 49	St. Louis, Mo. "	42
Washington, D. C.	41	West Chester, Penn. av.	39 to 54
Williamstown, Mass.	26 to 39		

Mr. FitzGerald found in some experiments at Chestnut Hill Reservoir that the yearly evaporation from a water surface is about 35 inches at that point. Mr. Trautwine says:

"By some trials by the writer in the tropics, ponds of pure water 8 ft. deep, in a stiff, retentive clay, and fully exposed to a hot sun all day, lost during the dry season, precisely 2 ins. in 16 days; or ⅛ inch per day (43 ins. in a year), while the evaporation from a tumbler was ¼ inch per day. The air in that region is highly charged with moisture, and the dews are heavy.

Every day during the trial the thermometer reached 115° to 125° in the sun."

The mean yearly percentage collected, as measured on the Boston Water Works has varied from 25 to 60 per cent., depending on the distribution of the rain during the several months. The mean is about 42 per cent. The minimum and not the mean figures are the ones to be used in making estimates for public supply.

The distribution of the rain has an important effect upon the per cent. of the total rainfall which can be collected. The four months of February, March, April and May, are those in which the quantity collected is large, seldom below 60 per cent., and when snow is melting often 100 and 200 per cent. of the rainfall.

Mr. FitzGerald gives the following figures.

MONTH.	RAINFALL.	COLLECTED.
July 1876	9.1 ins.	3.5 per cent.
Aug. 1878	6.9 "	12. " "
July 1879	6.5 "	7. " "
July 1880	6.3 "	5. " "
Sept. 1882	8.7 "	6. " "

PERCENTAGE OF RAINFALL COLLECTED ON THE SUDBURY RIVER WATER SHED.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly.	Amounts. July — Oct.
1875	7.6	76.5	76.5	162.9	59.5	24.0	16.0	12.8	10.4	23.8	46.5	110.7	44.9	16.0
1876	62.7	54.2	106.5	135.4	73.5	18.8	3.6	42.0	6.9	18.6	32.6	22.3	48.2	10.1
1877	36.5	206.9	102.7	120.3	67.0	42.5	12.2	5.9	31.9	13.2	42.2	264.4	57.9	11.7
1878	57.3	66.5	133.4	48.5	260.2	22.5	7.7	12.2	21.5	14.3	41.6	89.0	52.6	12.9
1879	50.4	77.4	80.9	114.1	125.8	18.8	7.1	10.8	12.9	15.6	13.2	19.0	45.3	10.3
1880	57.4	76.8	75.8	66.6	51.2	14.5	5.1	5.4	8.9	5.0	20.3	11.3	32.7	5.6
1881	13.1	52.8	122.8	131.5	48.3	42.2	20.7	19.2	12.8	11.0	16.4	34.4	45.9	15.2
1882	36.6	83.9	188.4	80.9	44.8	54.1	8.6	5.8	6.0	25.4	31.0	24.1	45.3	9.1
1883	20.9	42.4	159.1	124.4	39.4	21.3	7.6	18.8	10.2	5.8	19.2	9.6	33.6	7.8
1884	34.4	71.4	141.0	110.2	52.2	20.6	10.7	9.7	8.7	5.9	11.3	31.4	49.7	9.1
1885	46.1	55.6	258.3	85.7	67.4	25.3	7.7	5.9	14.4	11.6	32.9	75.9	42.8	8.8
1886	40.4	121.4	100.2	148.9	42.3	23.6	6.2	4.0	6.9	7.9	24.7	36.0	48.8	6.1
Averages	38.3	74.7	115.2	106.4	62.2	27.2	8.3	10.3	9.4	12.7	31.1	44.9	46.3	10.3

Statistics of consumption of water from "The Separate System of Sewerage" by STALEY & PIERSON.

CITIES	Average daily supply per Capita in Gallons. 1874	1884
Boston	60	110
Brooklyn	58	63
Buffalo	60	151
Chicago	84	145
Cincinnati	45	76
Cleveland	45	88
Detroit	87	120
Jersey City	86	136
Louisville	24	64
Philadelphia	58	81
Washington	138	165
Montreal	66	88

From J. T. Fanning, C. E., and J. J. R. Croes, C. E.

BASED UPON TOTAL POPULATION, CENSUS OF 1880.

NUMBER OF CITIES.	AMERICAN CITIES, POPULATION.	Average consumption of water per diem per capita.
49	10,000 to 15,000	76
33	15,000 to 20,000	69
17	20,000 to 25,000	71
41	25,000 to 50,000	86
11	50,000 to 75,000	80
4	75,000 to 100,000	95
13	100,000 to 250,000	102
4	250,000 to 500,000	89
4	500,000 and over	92

Compiled from J. J. R Croes' Statistical Tables by STALEY & PIERSON.

The maximum daily consumption frequently exceeds the average by 50 or 75 per cent., and the quantity of water used in American cities is greatly in excess of that used in England or on the continent. Of necessity the estimates for the early systems of public water supply in this country were based upon European experience, and considerable anxiety and annoyance has resulted.

Few cities in the United States have taken such thorough and systematic measures for the suppression of waste as Boston, Mass., and the results of the efforts were presented by Mr. Dexter Brackett, assistant engineer, in a paper presented to the N. E. W. W. Asso. at its New Bedford meeting in June, 1886 (Proc. Vol. 1, No. 2), and from this paper the following table is quoted:

	1883.		1884.		1885.		Saving effected 1883 to 1885.	
	Daily average Consumption in Gallons.	Gallons per head per day.	Daily average consumption in Gallons.	Gallons per head per day.	Daily average consumption in Gallons.	Gallons per head per day.	Gallons per Day.	Gallons per head per day.
Jan.	34715500	101.6	32162300	92.8	26711900	76.0	8003600	25.6
Feb.	32690700	95.5	24598000	70.9	31847400	90.5	843300	5.0
Mar.	34110700	99.6	23711900	68.3	27697200	78.6	7413500	21.0
Apr.	30617600	89.3	21505700	61.8	22720450	64.4	7896150	24.9
May	32169500	93.7	23708500	68.1	22168400	62.8	10001100	30.9
June	33419200	97.2	26184600	75.1	27214800	77.0	6205400	20.2
July	36774000	106.8	25409000	72.8	26606200	75.2	10167800	31.6
Aug.	37141000	107.8	25062500	71.7	24686400	69.7	12454600	38.1
Sept.	33645000	97.6	26389500	75.4	26493600	74.7	7151400	22.9
Oct.	29575800	85.6	25022900	71.5	24945500	70.3	4630300	15.3
Nov.	28839300	83.4	22954200	65.5	21942750	61.8	6896550	21.6
Dec.	30174200	87.2	24284800	69.0	24724900	69.5	5449300	17.7
Av'gs	32836900	94.9	25090500	71.9	25607200	72.4	7229700	22.5

PIPES.

When water is not to be conveyed through an open canal or ditch we must select some material for a tight conduit, and if we choose metal the conduit becomes a pipe, but if we use some form of masonry we retain the foundation word conduit for the name of the structure which conducts the water to a fixed point. Masonry conduits are not often used when water is to be conveyed under any considerable pressure.

Salt glazed vitrified clay pipe has been used to some extent for conveying water from the reservoir of a gravity system to the town, and in the opinion of Mr. Stephen E. Babcock, civil engineer of Little Falls, N. Y., an engineer who has used the pipe in this way, it is a great success, and its first cost is much below iron pipe of any kind.

There seems to be no form of water pipe so perfect as to make it fit for use in any and all cases and open to no improvement, but in the present state of knowledge, tarred cast iron seems to come the nearest to this desideratum. Wrought iron variously treated has been used, and when it is properly and thoroughly covered with cement it gives satisfaction, but the practical difficulties in the way of getting honest and thorough work at all times and under all circumstances, have given rise to unfavorable impressions of cement lined wrought iron pipe, among water works managers generally.

The National Tube Works Co. manufacture a special variety of coated wrought iron pipe which seems to promise very satisfactory results.

Table Showing Safe Thickness of Metal and Weight per Length, Including Bells, for Different Sizes of Cast Iron Pipe Under Various Heads of Water.

Size.	25 Ft. Head or 10.82 lbs. Pressure.		50 Ft. Head or 21.65 lbs. Pressure.		100 Ft. Head or 43.30 lbs. Pressure.		150 Ft. Head or 64.85 lbs. Pressure.		200 Ft. Head or 86.60 lbs. Pressure.		250 Ft. Head or 108.25 lbs. Pressure.		300 Ft. Head or 129.90 lbs. Pressure.	
	Thickn's of Metal.	Weight per Length.	Thickn's of Metal.	Weight per Length.	Thickn's of Metal.	Weight per Length.	Thickn's of Metal.	Weight per Length	Thickn's of Metal.	Weight per Length.	Thickn's of Metal.	Weight per Length.	Thickn's of Metal.	Weight per Length.
2	.225	54	.2946	63	.3126	67½	.3306	72	.3486	76½	.3666	81	.3846	86
3	.320	132	.3449	144	.3539	149	.3629	153	.3719	157	.3809	161	.3900	166
4	.335	180	.361[illegible]	197	.3732	204	.3852	211	.3972	218	.4092	226	.4212	235
6	.375	300	.3938	315	.4118	330	.4298	345	.4478	361	.4658	377	.4838	393
8	.433	456	.4224	445	.4504	475	.4744	502	.4984	529	.5224	557	.5464	584
10	442	576	.4590	600	.4890	641	.5190	682	.5490	723	.5790	766	.6090	808
12	446	720	.4916	768	.5276	826	.5636	885	.5996	944	.6356	1004	.6716	1064
14	....	....	.5242	952	.5662	1031	.6082	1111	.6502	1191	.6922	1272	.7342	1352
16	....	....	.5801	1215	.6048	1253	.6528	1360	.7008	1463	.7488	1568	.7968	1673
18	...	...	.5894	1370	.6434	1500	.6974	1630	.7514	1761	.8054	1894	.8594	2026
20	....	....	.6220	1603	.6820	1763	.7420	1924	.8020	2086	.8620	2248	.9220	2412
24	....	....	.6870	2120	.7592	2349	.8312	2580	.9032	2811	.9752	3045	1.0472	3279
30	....	....	.7850	3020	.8750	3376	.9650	3735	1.0550	4095	1.1450	4458	1.2350	4822
36	....	...	.8828	4070	.9908	4581	1.0988	5096	1.2068	5613	1.3148	6133	1.4228	6656
48	....	....	1.2224	6616	1.0784	7521	1.3664	8431	1.5104	9340	1.6544	10269	1.7984	11195

All pipe cast in lengths of 12 feet, except the 2 inch, which are cast 9 feet long.

Doubling the diameter of a pipe increases its capacity four times.

Friction of liquids in pipes increases as the square of the velocity.

There is no standard thickness for cast iron water pipe for any given pressure, and the variation in extreme cases is almost startling.

Papers and discussions upon this subject have been before both the American and the New England Water Works Associations, but the difficulties in the way of establishing a standard have not yet been surmounted.

Mr. P. H. Baermann, C.E., of Troy, N. Y., has suggested the following thicknesses for cast iron pipes under pressure due to a head of 300 feet.

Diam.	4"	6"	8"	10"	12"	16"	20"	24"	30"	36"	48"
Thickness	.35	.37	.40	.45	.54	.72	.90	1.08	1.35	1.62	2.16

—Proc. Eng. Club, Phila., Vol. III., No. 2.

TABLE OF CONTENTS IN CUB. FEET, AND IN U. S. GALLON,

(From Trautwine,)

Of 231 cub. ins. (or 7.4805 gallons to a cub. ft.); and for one foot of length of the cylinder. For the contents for a greater diam. than any in the table, take the quantity opposite one-*half* said diam.; and multiply it by 4. Thus, the number of cub. ft. in one ft. length of a pipe 80 inches in diam. is equal to 8.728 × 4 = 34.912 cub. ft. So also with gallons, and areas.

		For 1 foot in length.				For 1 foot in length.				For 1 foot in length.	
Diam. in Inches.	Diam. in decimals of a foot.	Cubic Feet. Also area in sq. ft.	Gallons of 231 Cub. Ins	Diam. in Inches	Diam. in decimals of a foot.	Cubic Feet. Also area in sq. ft.	Gallons of 231 Cub. Ins	Diam. in Inches	Diam. in decimals of a foot.	Cubic Feet. Also area in sq. ft.	Gallons of 231 Cub. Ins
¼	.0208	.0003	.0026	¾	.5625	.2485	1.859	19.	1.583	1.969	14.73
5-16	.0260	.0005	.0040	7.	.5833	.2673	1.999	½	1.625	2.074	15.52
⅜	.0313	.0008	.0057	¼	.6042	.2868	2.144	20.	1.666	2.182	16.32
7-16	.0365	.0010	.0078	½	.6250	.3068	2.295	½	1.708	2.292	17.15
½	.0417	.0014	.0102	¾	.6458	.3275	2.450	21.	1.750	2.405	17.99
9-16	.0469	.0017	.0129	8.	.6667	.3490	2.611	½	1.792	2.521	18.86
⅝	.0521	.0021	.0159	¼	.6875	.3713	2.777	22.	1.833	2.640	19.75
11-16	.0573	.0026	.0193	½	.7083	.3940	2.948	½	1.875	2.761	20.65
¾	.0625	.0031	.0230	¾	.7292	.4175	3 125	23.	1.917	2.885	22.58
13-16	.0677	.0036	.0270	9.	.7500	.4418	3.305	½	1.958	3.012	21.53
⅞	.0729	.0042	.0312	¼	.7708	.4668	3.492	24.	2.000	3.142	23 50
15-16	.0781	.0048	.0359	½	.7917	.4923	3 682	25.	2 083	3.409	25.50
1.	.0833	.0055	.0408	¾	.8125	.5185	3.879	26.	2.166	3.687	27.58
¼	.1042	.0085	.0638	10.	.8333	.5455	4.081	27.	2.250	3.976	29.74
½	.1250	.0123	.0918	¼	.8542	.5730	4.286	28.	2.333	4.276	31.99
¾	.1458	.0168	.1250	½	.8750	.6013	4.498	29.	2.416	4.587	34 31
2.	.1667	.0218	.1632	¾	.8958	.6303	4.714	30.	2.500	4.909	36.72
¼	.1875	.0276	.2066	11.	.9167	.6600	4.937	31.	2.583	5.241	39.21
½	.2083	.0341	.2550	¼	.9375	.6903	5 163	32.	2 666	5.585	41.78
¾	.2292	.0413	.3085	½	.9583	.7213	5 395	33.	2.750	5.940	44 43
3.	.2500	.0491	.3673	¾	.9792	.7530	5.633	34.	2.833	6.305	47.17
¼	.2708	.0576	.4310	12.	1 Foot.	.7854	5 876	35.	2 916	6.681	49.98
½	.2917	.0668	.4998	½	1.042	.8523	6.375	36.	3 000	7.069	52.88
¾	.3125	.0767	.5738	13.	1.083	.9218	6.895	37.	3.083	7.468	55 86
4.	.3333	.0873	.6528	½	1.125	.9940	7.435	38.	3.166	7.876	58 92
¼	.3542	.0985	.7370	14.	1.167	1.069	7.997	39.	3.250	8.296	62.06
½	.3750	.1105	.8263	½	1.208	1.147	8 578	40.	3.333	8.728	65.29
¾	.3958	.1231	.9205	15.	1.250	1 227	9.180	41.	3 416	9.168	68.58
5.	.4167	.1364	1.020	½	1.292	1.310	9 801	42.	3 500	9 620	71.96
¼	.4375	.1503	1.124	16.	1.333	1.396	10.44	43.	3.583	10.084	75.43
½	.4583	.1650	1.234	½	1.375	1 485	11.11	44.	3 666	10.560	79 00
¾	.4792	.1803	1.349	17.	1.417	1.576	11.79	45.	3.750	11.044	82.62
6.	.5000	.1963	1.469	½	1.458	1.670	12 50	46.	3 833	11 540	86.32
¼	.5208	.2130	1.594	18.	1.500	1.767	13 22	47.	3.916	12.048	90.12
½	.5417	.2305	1.724	½	1.542	1.867	13 97	48.	4.000	12 566	94.02

TABLE OF GALLONS.

	Cubic inches in a gallon.	Weight of a gallon in pounds Avoirdupois	Gallons in a cubic foot.	Weight of a cubic foot of water English standard, 62.3210-286 pounds Avoirdupios.
United States,	231.	8 33111	7.480519	
New York,	221.81918	8 00	7.901285	
Imperial,	277 274	10 00	6.232102	

From Trautwine, p. 243.

Approximate formula for the velocity of water in straight, smooth, cylindrical iron pipes. Given the total head and the length and diameter of the pipe.

Approximate mean velocity in feet per second =

$$m \times \sqrt{\frac{\text{Diam. in feet} \times \text{Total Head in feet.}}{\text{Total Length in feet} + 54 \text{ Diams. in feet.}}}$$

TABLE GIVING VALUES OF M.

$\sqrt{\frac{\text{Diam.} \times \text{Head}}{\text{Length} + 54 \text{ Diams.}}}$	DIAMETER OF PIPE IN FEET.							
	.05	.10	.50	1.	1.5	2.	3.	4.
	m.	m.	m.	m.	m.	m.	m.	m.
.005	29	31	33	35	37	40	44	47
.010	34	35	37	39	42	45	49	53
.020	39	40	42	45	49	52	56	59
.030	41	43	47	50	54	57	60	63
.050	44	47	52	54	56	60	64	67
.100	47	50	54	56	58	62	66	70
.200 and over.	48	51	55	58	60	64	67	70

The foregoing coefficients are approximate averages deduced from a large number of experiments. In most cases of pipes in fair condition, carefully laid and straight or nearly so, they should give results within, say from 5 to 10 per cent. of the truth. But slight differences as to roughness, etc., may cause much greater variations, especially in small pipes, for in such, a given roughness of surface bears a greater proportion to the whole area of cross section than in a pipe of large diameter. Extreme accuracy is not to be expected in such matters.

RELATIVE DISCHARGING CAPACITIES OF FULL SMOOTH PIPES.

Dia. in Feet.	Relative Discharg'g Power.	3	4	6	8	10	12	14	16	18	20	22	24	27	30	33	36	40	44	48	Drain in Inches.
d	$d^{\frac{5}{2}}$																				
4.	32.000	....	....	....	....	....	....	....	15.59	11.61	8.92	7.03	5.65	4.21	3.24	2.55	1.65	1.58	1.24	1	48
3.667	25.750	....	....	....	....	....	....	17.50	12.54	9.34	7.17	5.66	4.55	3.39	2.61	2.00	1.65	1.27	1	....	44
3.333	20.235	....	....	....	....	....	20.23	13.47	9.85	7.34	5.64	4.44	3.57	2.66	2.05	1.65	1.26	1	....	....	40
3.	15.588	....	....	....	....	....	15.58	8.41	7.59	5.65	4.34	3.42	2.74	2.05	1.58	1.24	1	....	....	....	36
2.750	12.541	....	....	....	34.55	19.78	12.54	8.52	6.11	4.55	3.49	2.75	2.21	1.65	1.27	1	....	....	....	....	33
2.500	9.859	....	....	....	27.09	15.54	9.85	6.54	4.80	3.57	2.74	2.16	1.74	1.29	1	....	....	....	....	....	30
2.250	7.594	....	....	42.95	16.61	9.96	7.59	5.16	3.70	2.75	2.11	1.67	1.34	1	....	....	....	....	....	....	27
2.	5.657	....	....	32.00	15.58	8.92	5.65	3.84	2.75	2.05	1.57	1.24	1	....	....	....	....	....	....	....	24
1.833	4.549	....	70.96	25.73	12.53	7.17	4.55	3.09	2.16	1.65	1.26	1	....	....	....	....	....	....	....	....	22
1.667	3.588	....	55.96	20.29	9.88	5.66	3.58	2.43	1.74	1.30	1	....	....	....	....	....	....	....	....	....	20
1.500	2.756	....	42.01	15.58	7.25	4.34	2.75	1.87	1.34	1	....	....	....	....	....	....	....	....	....	....	18
1.333	2.052	65.77	32.01	11.60	5.65	3.23	2.05	1.39	1	....	....	....	....	....	....	....	....	....	....	....	16
1.167	1.471	47.14	22.94	8.32	4.05	2.32	1.47	1	....	....	....	....	....	....	....	....	....	....	....	....	14
1.	1.	32.05	15.60	5.65	2.75	1.57	1	....	....	....	....	....	....	....	....	....	....	....	....	....	12
.833	.6339	20.31	9.88	3.58	1.74	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10
.667	.3629	11.63	5.66	2.05	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8
.500	.1768	5.66	2.75	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6
.333	.0641	2.05	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4
.250	.0312	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3

From J. T. Fanning's "Water Supply Engineering."

The foregoing table shows approximately the relative discharging powers of pipes of different diameters. In the second column the diameter 1 foot is assumed as a unit, and the figures show the relative discharging value of pipes whose diameter is given in the first column; for example, a pipe four feet in diameter will discharge 32 times as much water as one which is one foot in diameter, other things being equal; a pipe 3 ft. in diameter 15.588 times as much, one 2½ ft. in diameter, 9.859 times as much and so on.

The numbers at the intersections of the horizontal and vertical columns from the diameters in inches give also approximate relative discharging capacities. For example, a 48-inch pipe is equal to 15.59, 16-inch pipes, or 5.65 24-inch pipes or 1.58 40-inch pipes. Also for other diameters, we find that a 24-inch pipe is equal to 32 6-inch pipes or 2.05 18-inch pipes, and that a 12-inch pipe is equal to 5.65 6-inch pipes.

Kutter's formula is considered by many engineers to be the best general formula for determining the flow of water through conduits, channels and pipes. P. J. Flynn civil engineer, in VanNostrand's Science Series, No. 84, gives this formula in the following simplified form:—

$$V = \left\{ \frac{K}{1 + \left[44.41 \times \frac{n}{\sqrt{r}} \right]} \right\} \sqrt{rs}$$

In which V = velocity in feet per second

S = fall of water surface (h) in any distance (l) divided by that distance $= \frac{h}{l} =$ sine of slope.

r = hydraulic mean depth or the area of cross section of channel (a) in sq. ft., divided by its wetted perimeter (p) in lineal feet or $\frac{a}{p}$

The values for K and n to be taken from the following table:—

n		K
.009	in the case of well-planed timber in perfect order and alignment.	245.63
.010	plaster of pure cement; planed timber; glazed, coated or enamelled stone and iron pipes, in *perfect order*.	225.51
.011	plaster of 2 cement and 1 sand in good condition; iron, cement and terra-cotta pipes, well-jointed, in good order.	209.05
.012	unplaned timber when perfectly continuous on the inside. Flumes.	195.33
.013	ashlar and well-laid brick work; ordinary metal and in general the materials mentioned with n = .010 when not in perfect condition.	183.72
.015	second class or rough faced brick work; well-dressed stone work; foul and slightly tuberculated iron; cement and terra-cotta pipes with imperfect joints and in bad order, and canvas lining on wooden frames.	165.14
.017	brick work, ashlar and stone ware in an inferior condition; tuberculated iron pipes, and in general the materials mentioned with n = .013 when in bad order.	150.94
.020	cement rubble in an inferior condition; wooden troughs with battens on the inside two inches apart.	134.96
.0225	coarse dry set rubble in bad condition.	124.90

Flow of water over weirs having *sharp crests*, and without end contractions, Messrs Fteley & Stearns* give

$$Q = 3.31 \times L H^{\frac{3}{2}} + 0.007 L$$

in which

$Q =$ Volume in cu. ft. per second
$L =$ Length of weir in feet
$H =$ Head over weir in feet.

This formula was deduced from experiments made with depths of water varying from 0.08 ft. to 1.63 ft., and weirs 5 ft. and 19 ft. long. It is probably applicable with accuracy when the depths are greater.

The following table gives the amount in feet to be added algebraically to the depths observed on wide crest, to obtain the depth on a sharp crested weir of the same length which will give an equal volume of water.

* Boston Water Works—Additional Supply, 1882.

TABLE.

NOTE.—Use Table only when Sheet adheres to Crest.

Depth on Wide Crest.	Width of Crest.								
	1 in.	2 in.	3 in	4 in.	6 in.	8 in.	10 in.	12 in.	2 feet
0.05	—.0087	—.0097	—.0097	—.0093	—.0088	—.0086	—.0086	—.0086	—.0087
0.10	—.0068	—.0163	—.0177	—.0176	—.0170	—.0168	—.0169	—.0169	—.0172
0.15	+.0022	—.0166	—.0233	—.0244	—.0246	—.0248	—.0249	—.0251	—.0256
0.20	....	—.0118	—.0243	—.0294	—.0314	—.0323	—.0328	—.0331	—.0340
0.25	.....	—.0043	—.0219	—.0313	—.0370	—.0393	—.0402	—.0408	—.0423
0.30	....	+.0055	—.0167	—.0304	—.0414	—.0455	—.0473	—.0483	—.0504
0.35	....	....	—.0095	—.0270	—.0443	—.0509	—.0536	—.0554	—.0585
0.40	....	....	—.0010	—.0215	—.0453	—.0522	—.0597	—.0621	—.0665
0.45	....	....	+.0087	—.0145	—.0442	—.0581	—.0648	—.0683	—.0743
0.50	....	....	....	—.0065	—.0413	—.0600	—.0692	—.0740	—.0820
0.55	....	....	....	+.0024	—.0368	—.0622	—.0725	—.0791	—.0896
0.60	....	....	....	+.0120	—.0310	—.0587	—.0746	—.0833	—.0971
0.65	....	....	....	+.0221	—.0242	—.0558	—.0757	—.0867	—.1044
0.70	....	....	....	....	—.0168	—.0517	—.0753	—.0892	—.1116
0.75	....	....	....	....	—.0087	—.0469	—.0737	—.0907	—.1184
0.80	....	....	....	....	—.0001	—.0405	—.0709	—.0912	—.1250
0.85	....	....	....	....	+.0091	—.0338	—.0671	—.0906	—.1314
0.90	....	....	....	....	+.0186	—.0266	—.0623	—.0889	—.1375
0.95	....	....	....	....	+.0285	—.0190	—.0576	—.0861	—.1434
1.00	...	....	....	....	....	—.0109	—.0504	—.0825	—.1491
1.10	....	....	....	....	....	+.0066	—.0366	—.0729	—.1594
1.20	....	....	....	....	....	+.0253	—.0212	—.0606	—.1680
1.30	....	....	....	....	....	+.0447	—.0045	—.0467	—.1750
1.40	....	....	....	....	....	....	+.0133	—.0316	—.1802
1.50	....	....	....	....	....	....	+.0319	—.0154	—.1835

PRESSURE OF WATER.

The pressure of water in pounds per square inch for every foot in height to 300 feet; and then by intervals, to 1000 feet head. By this table, from the pounds pressure per square inch, the feet head is readily obtained; and *vice versa.*

Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.
1	0.43	65	28.15	129	55.88	193	83.60	257	111.32
2	0.86	66	28.58	130	56.31	194	84.03	258	111.76
3	1.30	67	29.02	131	56.74	195	84.47	259	112.19
4	1.73	68	29.45	132	57.18	196	84.90	260	112.62
5	2.16	69	29.88	133	57.61	197	85.33	261	113.06
6	2.59	70	30.32	134	58.04	198	85.76	262	113.49
7	3.03	71	30.75	135	58.48	199	86.20	263	113.92
8	3.46	72	31.18	136	58.91	200	86.63	264	114.36
9	3.89	73	31.62	137	59.34	201	87.07	265	114.79
10	4.33	74	32.05	138	59.77	202	87.50	266	115.22
11	4.76	75	32.48	139	60.21	203	87.93	267	115.66
12	5.20	76	32.92	140	60.64	204	88.36	268	116.09
13	5.63	77	33.35	141	61.07	205	88.80	269	116.52
14	6.06	78	33.78	142	61.51	206	89.23	270	116.96
15	6.49	79	34.21	143	61.94	207	89.66	271	117.39
16	6.93	80	34.65	144	62.37	208	90.10	272	117.82
17	7.36	81	35.08	145	62.81	209	90.53	273	118.26
18	7.79	82	35.52	146	63.24	210	90.96	274	118.69
19	8.22	83	35.95	147	63.67	211	91.39	275	119.12
20	8.66	84	36.39	148	64.10	212	91.83	276	119.56
21	9.09	85	36.82	149	64.54	213	92.26	277	119.99
22	9.53	86	37.25	150	64.97	214	92.69	278	120.42
23	9.96	87	37.68	151	65.40	215	93.13	279	120.85
24	10.39	88	38.12	152	65.84	216	93.56	280	121.29
25	10.82	89	38.55	153	66.27	217	93.99	281	121.72
26	11.26	90	38.98	154	66.70	218	94.43	282	122.15
27	11.69	91	39.42	155	67.14	219	94.86	283	122.59
28	12.12	92	39.85	156	67.57	220	95.30	284	123.02
29	12.55	93	40.28	157	68.00	221	95.73	285	123.45
30	12.99	94	40.72	158	68.43	222	96.16	286	123.89
31	13.42	95	41.15	159	68.87	223	96.60	287	124.32
32	13.86	96	41.58	160	69.31	224	97.03	288	124.75
33	14.29	97	42.01	161	69.74	225	97.46	289	125.18
34	14.72	98	42.45	162	70.17	226	97.90	290	125.62
35	15.16	99	42.88	163	70.61	227	98.33	291	126.05
36	15.59	100	43.31	164	71.04	228	98.76	292	126.48
37	16.02	101	43.75	165	71.47	229	99.20	293	126.92
38	16.45	102	44.18	166	71.91	230	99.63	294	127.35
39	16.89	103	44.61	167	72.34	231	100.06	295	127.78
40	17.32	104	45.05	168	72.77	232	100.49	296	128.22
41	17.75	105	45.48	169	73.20	233	100.93	297	128.65
42	18.19	106	45.91	170	73.64	234	101.36	298	129.08
43	18.62	107	46.34	171	74.07	235	101.79	299	129.51
44	19.05	108	46.78	172	74.50	236	102.23	300	129.95
45	19.49	109	47.21	173	74.94	237	102.66	310	134.28
46	19.92	110	47.64	174	75.37	238	103.09	320	138.62
47	20.35	111	48.08	175	75.80	239	103.53	330	142.95
48	20.79	112	48.51	176	76.23	240	103.96	340	147.28
49	21.22	113	48.94	177	76.67	241	104.39	350	151.61
50	21.65	114	49.38	178	77.10	242	104.83	360	155.94
51	22.09	115	49.81	179	77.53	243	105.26	370	160.27
52	22.52	116	50.24	180	77.97	244	105.69	380	164.61
53	22.95	117	50.68	181	78.40	245	106.13	390	168.94
54	23.39	118	51.11	182	78.84	246	106.56	400	173.27
55	23.82	119	51.54	183	79.27	247	106.99	500	216.58
56	24.26	120	51.98	184	79.70	248	107.43	600	259.90
57	24.69	121	52.41	185	80.14	249	107.86	700	303.22
58	25.12	122	52.84	186	80.57	250	108.29	800	346.54
59	25.55	123	53.28	187	81.00	251	108.73	900	389.86
60	25.99	124	53.71	188	81.43	252	109.16	1000	433.18
61	26.42	125	54.15	189	81.87	253	109.59		
62	26.85	126	54.58	190	82.30	254	110.03		
63	27.29	127	55.01	191	82.73	255	110.46		
64	27.72	128	55.44	192	83.17	256	110.89		

Friction-loss in Pounds Pressure, for each 100 feet of length in different size clean Iron Pipes discharging given quantities of Water Per Minute. Also Velocity of flow in Pipe, in feet per second.

G. A. Ellis, C. E.

Gallons discharged per minute.	½ Inch.		¾ Inch.		1 Inch.		1¼ Inch.		1½ Inch.		2 Inch		2½ Inch.		3 Inch.		4 Inch.		6 Inch.		Gallons discharged per minute.
	Veloc. in Pipe per second.	Friction Loss in Pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in Pounds.	Veloc. in Pipe per second.	Friction Loss in Pounds.	
5	8.17	24.6	3.63	3.3	2.04	0.84	1.31	0.31	0.91	0.12											5
10	16.3	96.0	7.25	13.0	4.08	3.16	2.61	1.05	1.82	0.47	1.02	0.12									10
15			10.9	28.7	6.13	6.98	3.92	2.38	2.73	0.97											15
20			14.5	50.4	8.17	12.3	5.22	4.07	3.63	1.66	2.04	0.42									20
25			18.1	78.0	10.2	19.0	6.53	6.40	4.54	2.62			1.63	0.21	1.13	0.10					25
30					12.3	27.5	7.84	9.15	5.45	3.75	3.06	0.91									30
35					14.3	37.0	9.14	12.4	6.36	5.05											35
40					16.3	48.0	10.4	16.1	7.26	6.52	4.09	1.60									40
45							11.7	20.2	8.17	8.15											45
50							13.1	24.9	9.08	10.0	5.11	2.44	3.26	0.81	2.27	0.35	1.28	0.09			50
75							19.6	56.1	13.6	22.4	7.66	5.32	4.90	1.80	3.40	0.74					75
100									18.2	39.0	10.2	9.46	6.53	3.20	4.54	1.31	2.55	0.33	1.13	0.05	100
125											12.8	14.9	8.16	4.89	5.67	1.99					125
150											15.3	21.2	9.80	7.00	6.81	2.85	3.83	0.69	1.70	0.10	150
175											17.1	28.1	11.4	9.46	7.94	3.85					175
200											20.4	37.5	13.1	12.47	9.08	5.02	5.11	1.22	2.27	0.17	200
250													16.3	19.66	11.3	7.76	6.39	1.89	2.84	0.26	250
300													19.6	28.06	13.6	11.2	7.66	2.66	3.40	0.37	300
350															15.9	15.2	8.94	3.65	3.97	0.50	350
400															18.2	19.5	10.2	4.73	4.54	0.65	400
450															20.4	25.0	11.5	6.01	5.11	0.81	450
500															22.7	30.8	12.8	7.43	5.67	0.96	500

Friction-Loss in Pounds Pressure, for each 100 feet of length in different size clean Iron Pipes discharging given quantities of Water per Minute. Also Velocity of flow in Pipe, in feet per second.

G. A. Ellis, C. E.

Gallons discharged per minute.	6 Inch.		8 Inch.		10 Inch.		12 Inch.		14 Inch.		16 Inch.		18 Inch.		20 Inch.		24 Inch.		30 Inch.		Gallons discharged per minute.
	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	Veloc. in Pipe per second.	Friction Loss in pounds.	
250	2.84	0.26	1.59	0.07	1.02	0.03	0.71	0.01	......	......	......	......	......	......	......	......	......	......	......	......	250
500	5.67	0.98	3.19	0.25	2.04	0.09	1.42	0.04	1.04	0.017	0.80	0.009	0.63	0.005	......	......	......	......	......	......	500
750	8.51	2.21	4.79	0.53	3.06	0.18	2.13	0.08	......	......	......	......	......	......	......	......	......	......	......	......	750
1,000	11.3	3.88	6.38	0.94	4.08	0.32	2.84	0.13	2.08	0.062	1.60	0.036	1.26	0.020	1.02	0.012	0.72	0.005	0.45	0.002	1,000
1,250	......	......	7.97	1.46	5.10	0.49	3.55	0.20	......	......	......	......	......	......	......	......	......	......	......	......	1,250
1,500	......	......	9.57	2.09	6.12	0.70	4.26	0.29	3.13	0.135	2.39	0.071	1.89	0.040	......	......	......	......	......	......	1,500
1,750	......	......	......	......	7.15	0.95	4.96	0.38	......	......	......	......	......	......	......	......	......	......	......	......	1,750
2,000	......	......	......	......	8.17	1.23	5.67	0.49	4.17	0.234	3.19	0.123	2.52	0.071	2.04	0.042	1.44	0.020	0.91	0.006	2,000
2,250	......	......	......	......	......	......	6.38	0.63	......	......	......	......	......	......	......	......	......	......	......	......	2,250
2,500	......	......	......	......	......	......	7.09	0.77	5.21	0.362	3.99	0.188	3.15	0.107	......	......	......	......	......	......	2,500
3,000	......	......	......	......	......	......	8.51	1.11	6.25	0.515	4.79	0.267	3.78	0.150	3.06	0.091	2.16	0.047	1.36	0.012	3,000
3,500	......	......	......	......	......	......	......	......	7.29	0.697	5.59	0.365	4.41	0.204	......	......	......	......	......	......	3,500
4,000	......	......	......	......	......	......	......	......	8.34	0.910	6.38	0.472	5.04	0.263	4.08	0.158	2.88	0.067	1.82	0.022	4,000
4,500	......	......	......	......	......	......	......	......	......	......	7.18	0.593	5.67	0.333	......	......	......	......	......	......	4,500
5,000	......	......	......	......	......	......	......	......	......	......	7.98	0.730	6.30	0.408	5.11	0.244	3.60	0.102	2.27	0.035	5,000
6,000	......	......	......	......	......	......	......	......	......	......	......	......	7.56	0.585	6.13	0.348	4.32	0.146	2.72	0.048	6,000
7,000	......	......	......	......	......	......	......	......	......	......	......	......	......	......	7.15	0.472	5.04	0.196	3.18	0.065	7,000
8,000	......	......	......	......	......	......	......	......	......	......	......	......	......	......	8.17	0.612	5.76	0.255	3.63	0.083	8,000
9,000	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	6.47	0.323	4.08	0.105	9,000
10,000	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	7.19	0.398	4.54	0.131	10,000

FRICTION.

Friction-loss in pounds pressure in 2½ inch fire hose for each 100 feet of length at each 5 gallons discharged per minute — *G. A. Ellis, C. E.*

Gallons discharged per minute.	Friction-Loss.		Gallons discharged per minute.	Friction-Loss.		Gallons discharged per minute.	Friction-Loss.	
	Rubber Hose.	Leather Hose.		Rubber Hose.	Leather Hose.		Rubber Hose.	Leather Hose.
50	1.40	2.90	155	8.43	10.83	260	24.29	27.81
55	1.53	3.07	160	8.99	11.44	265	25.26	28.84
60	1.69	3.27	165	9.56	12.06	270	26.26	29.90
65	1.86	3.48	170	10.16	12.71	275	27.27	30.97
70	2.06	3.72	175	10.77	13.37	280	28.31	32.07
75	2.27	3.97	180	11.41	14.06	285	29.36	33.18
80	2.51	4.25	185	12.06	14.76	290	30.44	34.32
85	2.76	4.54	190	12.74	15.49	295	31.53	35.47
90	3.04	4.86	195	13.43	16.23	300	32.65	36.65
95	3.33	5.19	200	14.15	17.00	310	34.94	39.07
100	3.65	5.55	205	14.88	17.79	320	37.31	41.57
105	3.98	5.93	210	15.64	18.60	330	39.76	44.15
110	4.34	6.33	215	16.41	19.43	340	42.29	46.81
115	4.71	6.75	220	17.21	20.28	350	44.90	49.55
120	5.11	7.19	225	18.02	21.15	360	47.59	52.38
125	5.52	7.65	230	18.86	22.04	370	50.36	55.29
130	5.96	8.13	235	19.71	22.95	380	53.21	58.28
135	6.41	8.63	240	20.59	23.88	390	56.14	61.35
140	6.89	9.15	245	21.48	24.83	400	59.15	64.50
145	7.39	9.69	250	22.40	25.80			
150	7.90	10.25	255	23.33	26.79			

Iron pipe having a continuous flow of water through it, will corrode much faster than one having but a slight or no current through it. An 8-inch cast iron pipe, coated, 1000 feet long, having a continuous current through it, being supplied by a 24-inch pipe and discharging through an open end, discharged but ⅘ as much water at the end of six years as when first put down.

A recent experiment at Holyoke, Mass., showed that a 3-inch Globe valve in a line of 3-inch pipe caused a decrease in pressure of from 80 lbs. to 41 lbs. per square inch, while a three inch Chapman valve, in the same place, only caused a fall from 80 lbs. to 76 lbs. per square inch, both valves being full open and the pipe discharging free into the air.

TABLE SHOWING FRICTIONAL HEADS AT GIVEN RATES OF DISCHARGE IN CLEAN CAST-IRON PIPES FOR EACH 1000 FEET OF LENGTH, condensed from elaborate tables prepared by Messrs. Geo. A. Ellis and A. H. Howland, Civil Engineers, Boston, Mass.

U. S. gallons discharged per minute.	U. S. gallons discharged per twenty-four hours.	4-Inch Pipe.			6-Inch Pipe.			8-Inch Pipe.			10-Inch Pipe.			12-Inch Pipe.			14-Inch Pipe.		
		Velocity in feet.	Friction Head.		Velocity in feet.	Friction Head.		Velocity in feet.	Friction Head.		Velocity in feet.	Fricton Head.		Velocity in feet.	Friction Head.		Velocity in feet.	Friction Head.	
			Feet.	Pounds		Feet.	Pounds		Feet.	Pounds		Feet.	Pounds		Feet.	Pounds		Feet.	Pounds
25	36000	.64	.59	.26	.28	.11	.05	.16	.04	.02	.10	.02	.01	.07	.01	.....	..	....	....
50	72000	1.28	2.01	.87	.57	.32	.14	.32	.10	.04	.20	.04	.02	.14	.02	.01	.10	.01	.....
100	144000	2.55	7.36	3.19	1.13	1.08	.47	.64	.29	.13	.41	.11	.05	.28	.05	.02	.21	.03	.01
150	216000	3.83	16.05	6.95	1.70	2.28	.99	.96	.60	.26	.61	.22	.10	.43	.10	.04	.31	.05	.02
200	288000	5.11	28.09	12.17	2.27	3.92	1.70	1.28	1.01	.44	.82	.36	.16	.57	.16	.07	.42	.08	.04
250	360000	6.37	43.47	18.83	2.84	6.00	2.60	1.60	1.52	.66	1.02	.54	.23	.71	.24	.10	.52	.12	.05
300	432000	7.66	62.20	26.94	3.40	8.52	3.69	1.91	2.13	.92	1.23	.75	.32	.85	.32	.14	.63	.16	.07
350	504000	8.94	84.26	36.50	3.97	11.48	4.97	2.23	2.85	1.24	1.43	.99	.43	.99	.43	.18	.73	.21	.09
400	576000	10.21	109.68	47.50	4.54	14.89	6.45	2.55	3.68	1.59	1.63	1.27	.55	1.13	.54	.23	.83	.27	.12
450	648000	11.49	138.43	59.96	5.11	18.73	8.11	2.87	4.61	2.00	1.83	1.58	.69	1.28	.67	.29	.94	.33	.14
500	720000	12.77	170.53	73.87	5.67	23.01	9.97	3.19	5.64	2.44	2.04	1.93	.84	1.42	.81	.35	1.04	.40	.17
600	864000	15.32	244.76	106.02	6.81	32.89	14.25	3.83	8.03	3.48	2.45	2.72	1.18	1.70	1.14	.49	1.25	.55	.24
700	1008000	17.87	332.36	143.98	7.94	44.54	19.08	4.47	10.83	4.69	2.86	3.66	1.58	1.98	1.52	.66	1.46	.73	.32
800	1152000	.....	.....	.....	9.08	57.95	25.10	5.09	14.05	6.08	3.27	4.73	2.05	2.27	1.96	.85	1.67	.94	.41
900	1296000	.....	.....	.....	10.21	73.12	31.67	5.74	17.68	7.69	3.68	5.93	2.57	2.55	2.45	1.06	1.88	1.17	.51
1000	1440000	.....	.....	.....	11.35	90.05	38.99	6.38	21.74	9.41	4.08	7.28	3.15	2.84	3.00	1.30	2.08	1.43	.62
1200	1728000	.....	.....	.....	13.61	129.20	55.96	7.66	31.10	13.47	4.90	10.38	4.50	3.40	4.26	1.85	2.50	2.02	.88
1400	2016000	.....	.....	.....	15.88	175.38	75.97	8.94	42.13	18.25	5.72	14.02	6.07	3.97	5.74	2.49	2.91	2.72	1.18
1600	2304000	.....	.....	.....	18.15	228.62	99.03	10.21	54.84	23.75	6.53	18.22	7.89	4.54	7.44	3.22	3.33	3.51	1.52
1800	2592000	.....	.....	.....	20.42	288.90	125.14	11.47	69.22	29.98	7.35	22.96	9.95	5.11	9.36	4.06	3.75	4.41	1.91
2000	2880000	.....	.....	.....	22.69	356.22	154.30	12.77	85.27	36.93	8.17	28.25	12.34	5.67	11.50	5.00	4.17	5.41	2.34
2500	3600000	.....	.....	.....	.....	.....	.....	15.96	132.70	57.49	10.21	43.87	19.00	7.09	17.82	7.72	5.21	8.35	3.62
3000	4320000	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.25	62.92	27.25	8.51	25.51	11.05	6.25	11.93	5.17
3500	5040000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.93	34.58	14.98	7.29	16.14	6.99
4000	5760000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.34	21.00	9.10
4500	6480000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.38	20.49	11.47

TABLE SHOWING FRICTIONAL HEADS AT GIVEN RATES OF DISCHARGE IN CLEAN CAST-IRON PIPES FOR EACH 1000 FEET OF LENGTH, condensed from elaborate tables prepared by Messrs. Geo. A. Ellis and A. H. Howland, Civil Engineers, Boston, Mass.

U. S. gallons discharged per minute.	U. S. gallons discharged per twenty-four hours.	16-Inch Pipe.			18-Inch Pipe.			20-Inch Pipe.			24-Inch Pipe.			30-Inch Pipe.			36-Inch Pipe.		
		Velocity in feet.	Friction Head.		Velocity in feet.	Friction Head.		Velocity in feet.	Friction Head.		Velocity in feet.	Fricton Head.		Velocity in feet.	Friction Head.		Velocity in feet.	Friction Head.	
			Feet.	Pounds		Feet.	Pounds		Feet.	Pounds		Feet.	Pounds		Feet.	Pounds		Feet.	Pounds
500	720000	.80	.22	.09	.63	.13	.06	.51	.08	.04	.35	.04	.02	.23	.01	.00	.16	.01	.00
1000	1440000	1.60	.76	.34	1.26	.44	.19	1.02	.27	.12	.71	.12	.05	.45	.04	.02	.32	.02	.01
1500	2160000	2.39	1.63	.71	1.89	.93	.40	1.53	.56	.24	1.06	.24	.10	.68	.09	.04	.47	.04	.02
2000	2880000	3.19	2.82	1.22	2.52	1.60	.69	2.04	.96	.42	1.42	.41	.18	.91	.15	.06	.63	.06	.03
2500	3600000	3.99	4.34	1.88	3.15	2.45	1.06	2.55	1.47	.64	1.77	.62	.27	1.13	.22	.09	.79	.09	.04
3000	4320000	4.79	6.19	2.68	3.78	3.48	1.51	3.06	2.09	.90	2.13	.87	.38	1.36	.30	.13	.95	.13	.06
3500	5040000	5.59	8.37	3.63	4.41	4.70	2.03	3.57	2.81	1.22	2.48	1.16	.50	1.59	.40	.17	1.10	.17	.07
4000	5760000	6.38	10.87	4.71	5.04	6.09	2.64	4.08	3.64	1.58	2.84	1.50	.65	1.82	.52	.22	1.26	.22	.09
4500	6480000	7.18	13.70	5.93	5.67	7.67	3.32	4.59	4.58	1.98	3.19	1.88	.82	2.04	.64	.28	1.42	.27	.12
5000	7200000	7.98	16.85	7.30	6.30	9.43	4.08	5.11	5.62	2.43	3.55	2.31	1.00	2.27	.78	.34	1.58	.33	.14
5500	7920000	8.78	20.33	8.71	6.93	11.38	4.92	5.62	6.77	2.93	3.90	2.77	1.20	2.50	.94	.41	1.73	.39	.17
6000	8640000	....	....	....	7.57	13.49	5.84	6.13	8.03	3.48	4.26	3.28	1.42	2.72	1.11	.48	1.89	.46	.20
7000	10080000	....	....	....	....	....	....	7.15	10.86	4.71	4.96	4.43	1.92	3.18	1.49	.65	2.21	.62	.27
8000	11520000	....	....	....	....	....	....	....	....	....	5.67	5.75	2.49	3.63	1.93	.84	2.52	.80	.35
9000	12960000	....	....	....	....	....	....	....	....	....	6.38	7.25	3.14	4.08	2.43	1.05	2.84	1.00	.43
10000	14400000	....	....	....	....	....	....	....	....	....	....	....	....	4.54	2.98	1.29	3.15	1.23	.53
11000	15840000	....	....	....	....	....	....	....	....	....	....	....	....	5.00	3.59	1.55	3.46	1.47	.64
12000	17280000	....	....	....	....	....	....	....	....	....	....	....	....	5.44	4.25	1.84	3.78	1.74	.75
13000	18720000	....	....	....	....	....	....	....	....	....	....	....	....	5.90	4.97	2.15	4.09	2.03	.88
14000	20160000	....	....	....	....	....	....	....	....	....	....	....	....	6.36	5.75	2.49	4.41	2.35	1.02
15000	21600000	....	....	....	....	....	....	....	....	....	....	....	....	6.80	6.58	2.85	4.73	2.69	1.17
16000	23040000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.05	3.46	1.32
17000	24480000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.36	3.43	1.49
18000	25020000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.68	3.83	1.66
20000	2880000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.30	4.71	2.04

Table of Friction Heads in Feet in Small Pipes 100 Feet Long under given Discharge.

Gallons discharged per minute.	Gallons discharged per 24 hours.	½-in Diam. Velocity in ft. per second.	½-in Diam. Friction head in feet.	¾-in. Diam. Velocity in ft. per second.	¾-in. Diam. Friction head in feet.	1-in. Diam. Velocity in ft. per second.	1-in. Diam. Friction head in feet.	1¼-in. Diam. Velocity in ft. per second.	1¼-in. Diam. Friction head in feet.
2.5	3,600	4.08	18.29	1.81	2.78	1.02	.74	....	....
5	7,200	8.17	66.82	3.63	9.40	2.04	2.52	1.31	.83
7.5	10,800	12.25	142.9	5.44	20.17	3.06	5.14	....	....
10	14,400	16.33	243.3	7.25	34.77	4.08	8.75	2.62	2.85
12.5	18,000	....	....	9.06	52.11	5.10	13.22	....	....
15	21,600	....	....	10.87	73.61	6.13	18.84	3.92	5.90
17.5	25,200	....	....	12.69	98.80	7.15	25.14	....	....
20	28,800	....	....	14.50	127.6	8.17	32.27	5.22	10.21
22.5	32,400	....	....	16.31	160.7	9.18	40.17	....	....
25	36,000	....	....	18.12	197.7	10.20	48.90	6.53	15.50
30	43,200	....	....	....	....	12.23	68.70	7.84	22.34
35	50,400	....	....	....	....	14.25	92.10	9.14	28.99
40	57,600	....	....	....	....	16.29	116.8	10.45	37.29
45	64,800	....	....	....	....	18.34	150.6	11.76	46.47
50	72,000	....	....	....	....	20.37	186.7	13.07	57.16
55	79,200	....	....	....	....	....	....	14.38	68.62
60	86,400	....	....	....	....	....	....	15.69	81.35
65	93,600	....	....	....	....	....	....	17.00	95.11
70	100,800	....	....	....	....	....	....	18.31	109.9
75	108,000	....	....	....	....	....	....	19.62	126.1

		1½-in. Diam.		2-in. Diam.		2½-in. Diam.		3-in. Diam.	
5	7,200	.91	.51	1	....	....	....	....	....
10	14,400	1.82	1.33	1.02	.31	....	....	....	....
15	21,600	2.73	2.80	....	....	....	....	....	....
20	28,800	3.63	4.59	2.04	1.17	....	....	....	....
25	36,000	4.54	6.99	....	....	1.63	.58	....	....
30	43,200	5.45	9.86	3.06	2.36	....	....	....	....
35	50,400	6.36	13.14	....	....	....	....	....	....
40	57,600	7.26	16.94	4.09	4.17	....	....	....	....
45	64,800	8.17	21.09	....	....	....	....	....	....
50	72,000	9.08	25.66	5.11	6.34	3.26	2.10	2.27	.88
60	86,400	10.90	36.15	6.13	8.92	....	...	....	....
70	100,800	12.72	48.84	7.15	11.83	....	....	....	....
75	108,000	....	....	....	....	4.90	4.58	3.40	1.90
80	115,200	14.54	63.53	8.18	15.27	....	....	....	....
90	129,600	16.36	79.78	9.20	19.11	....	....	....	....
100	144,000	18.17	98.23	10.22	23.23	6.53	7.95	4.54	3.29
125	180,000	....	....	12.80	35.78	8.16	12.10	5.67	5.00
150	216,000	....	....	15.3	50.60	9.80	17.05	6.81	7.05
175	252,000	....	....	17.9	69.13	11.43	22.88	7.94	9.41
200	288,000	....	....	20.4	89.51	13.07	29.67	9.08	12.13
225	324,000	....	....	....	....	14.70	37.14	10.22	15.17
250	360,000	....	....	....	....	16.34	45.81	11.36	18.69
275	396,000	....	....	....	....	17.97	55.32	12.50	22.52
300	432,000	....	....	....	....	19.60	65.68	13.64	26.26
350	468,000	....	....	....	....	21.24	77.01	15.91	35.80
400	576,000	....	....	....	....	22.87	89.11	18.18	46.64
450	648,000	....	....	....	....	....	....	20.45	88.70
500	720,000	....	....	....	....	....	....	22.72	73.82

TABLE (Ellis).

Theoretical Discharge of Circular Orifices or Nozzles.—Diameters in Inches.

Note.—The actual discharge will be less than the theoretical one given below, varying with the form of nozzle or tube through which the water flows. For a ring nozzle 64 per centum, and for a good form of tapering smooth nozzle about 82 per centum, can be assumed as the actual discharge.

Head.		Velocity of discharge in feet per second.	Number of United States Gallons of 231 Cubic Inches discharged per minute.																		
Lbs	Feet.		$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	Lbs.
10	23.1	38.58	0.37	1.48	3.30	5.90	13.2	23.6	36.8	53.2	72.2	94.4	119	148	178	212	289	378	478	590	10
15	34.7	47.25	0.45	1.81	4.02	7.23	16.2	28.7	45.0	65.1	88.4	116	146	181	218	260	354	463	586	723	15
20	46.2	54.55	0.52	2.09	4.66	8.35	18.7	33.4	52.0	75.3	102	134	169	209	252	300	409	534	676	835	20
25	57.8	60.99	0.58	2.33	5.23	9.33	20.9	37.2	58.2	84.1	114	149	189	233	282	336	457	597	756	933	25
30	69.3	66.82	0.64	2.56	5.71	10.2	22.8	40.9	63.7	92.2	125	164	207	256	309	368	501	654	828	1022	30
35	80.9	72.16	0.69	2.76	6.16	11.0	24.7	44.2	68.8	99.6	135	177	223	276	334	397	541	707	895	1104	35
40	92.4	77.14	0.74	2.95	6.60	11.8	26.4	47.2	73.6	106	144	189	239	295	357	425	578	755	956	1180	40
45	104.0	81.83	0.78	3.13	6.99	12.5	28.0	50.2	78.1	113	153	200	253	313	378	450	613	801	1014	1252	45
50	115.5	86.26	0.82	3.30	7.37	13.2	29.5	52.8	82.3	119	161	211	267	330	399	475	646	845	1069	1320	50
55	127.1	90.46	0.86	3.46	7.73	13.8	30.9	55.4	86.3	125	169	221	280	346	418	498	678	886	1122	1385	55
60	138.6	94.49	0.90	3.62	8.08	14.5	32.3	57.8	90.1	130	177	231	293	362	437	520	708	925	1171	1446	60
65	150.2	98.35	0.94	3.77	8.40	15.1	33.6	60.2	93.8	136	184	241	305	377	455	542	737	963	1219	1506	65
70	161.7	102.06	0.97	3.91	8.73	15.6	34.9	62.5	97.4	141	191	250	316	391	472	562	765	999	1265	1561	70
75	173.3	105.65	1.01	4.04	9.03	16.2	36.1	64.6	101	146	198	259	327	404	488	582	792	1034	1309	1616	75
80	184.8	109.11	1.04	4.18	9.33	16.7	37.8	66.6	104	150	204	267	338	418	504	601	818	1068	1352	1669	80
85	196.4	112.46	1.07	4.31	9.62	17.2	38.5	68.8	107	155	210	275	348	431	520	620	843	1101	1394	1720	85
90	207.9	115.72	1.10	4.43	9.89	17.7	39.6	70.8	110	160	217	283	358	443	535	637	867	1133	1434	1770	90
95	219.5	118.89	1.13	4.55	10.2	18.2	40.7	72.8	113	164	223	291	368	455	550	655	891	1164	1474	1820	95
100	231.1	121.98	1.16	4.67	10.4	18.7	41.7	74.6	116	168	228	299	378	467	564	672	914	1194	1512	1866	100
105	242.6	125.00	1.19	4.78	10.7	19.1	42.8	76.5	119	172	234	306	387	478	578	688	937	1224	1549	1912	105
110	254.2	127.94	1.22	4.90	10.9	19.6	43.8	78.3	122	177	239	313	396	490	591	705	959	1253	1586	1957	110
115	265.7	130.82	1.25	5.01	11.2	20.0	44.8	80.1	125	181	245	320	405	501	605	720	980	1281	1621	2002	115
120	277.3	133.63	1.27	5.12	11.4	20.4	45.7	81.8	127	184	250	327	414	512	618	736	1001	1308	1656	2044	120
125	288.8	136.38	1.30	5.22	11.7	20.9	46.7	83.5	130	188	255	334	422	522	630	751	1022	1335	1691	2086	125
130	300.4	139.08	1.33	5.32	11.9	21.3	47.6	85.1	133	192	260	341	431	532	643	766	1042	1363	1724	2128	130

The following tables of friction loss, and of hydrant and hose stream data, are taken from Fanning's "Water Supply," and were computed from the published data of the valuable experiments of Messrs. Ellis and Leshure.

Pounds Pressure Lost by Friction in each 100 ft. of 2½ in. Fire Hose for given discharges of water per minute.

Diam. of Nozzle.		Pressure at Hose Nozzle.								
	Head in lbs. per sq. in.	20	30	40	50	60	70	80	90	100
	Head in feet	46.2	69.3	92 4	115 5	138.6	161.7	184.8	207.9	231.0
in.										
1	Galls. discharged	110	134	155	173	189	205	219	232	245
	Rubber Hose, lbs.	4.35	6 40	8.40	10.20	12.80	14.80	17.00	19 20	20 50
	Leather Hose, lbs.	6.33	8.53	10.83	13.10	15.34	17.79	20 11	22.40	24 83
1⅛	Galls. discharged	139	170	196	219	240	259	277	294	310
	Rubber Hose, lbs.	6.79	10.16	13.60	17.05	20.59	24.00	27.00	30.00	33 00
	Leather Hose, lbs.	9.05	12.71	16.38	20.11	23.88	27.61	31.41	35.24	39.07
1¼	Galls. discharged	171	210	242	271	297	320	342	363	383
	Rubber Hose, lbs.	10.28	15.64	20.85	25.46	29.50	39.00	43.81	49.42	55 00
	Leather Hose, lbs.	12.84	19.00	24.07	30.11	35.94	41.57	47.36	53.25	59.20
1⅜	Galls. discharged	207	253	293	327	358	387	413	439	462
	Rubber Hose, lbs.	15.00	22 96	29.40	40.50	48.20	55.70	64.70	72.00	79.26
	Leather Hose, lbs.	18.81	26.39	35.01	43 38	52.00	60.40	68.59	76.73	84.87

Horizontal and Vertical Distances reached by Jets.

Diam. of Nozzle.		Pressure at Nozzle.								
	Head in lbs. per sq. in.	20	30	40	50	60	70	80	90	100
	Head in feet	46.2	69.3	92.4	115.5	138.6	161.7	184.8	207.9	231.0
in.										
1	Gallons discharged	110	134	155	173	189	205	219	232	245
	Horizontal distance of jet	70	90	109	126	142	156	168	178	186
	Vertical " "	43	62	79	94	108	121	131	140	148
1⅛	Gallons discharged	131	170	196	219	240	259	277	294	310
	Horizontal distance of jet	71	93	113	132	148	163	175	186	193
	Vertical " "	43	63	81	97	112	125	137	148	157
1¼	Gallons discharged	171	210	242	271	297	320	342	363	383
	Horizontal distance of jet	73	96	118	138	156	172	186	198	207
	Vertical " "	43	63	82	99	115	129	142	154	164
1⅜	Gallons discharged	207	253	293	327	358	387	413	439	462
	Horizontal distance of jet	75	100	124	146	166	184	200	213	224
	Vertical " "	44	65	85	102	118	133	146	158	169

WATER MOTORS.

Circulars issued by parties interested in the sale of water motors, do not furnish very definite information as to the quantity of water needed to develop a given quantity of power, and in making estimates upon this point the following formula may be used.

Let m = galls. per min.
" h = head in feet under which water is delivered to motor.
8.3 = constant (weight of 1 gall.)
H.P. = horse power.

$$H.P. = \frac{mh\ 8.3}{33000} = mh\ .0002527$$

and

$$m = \frac{H.P.}{h\ .0002527}$$

These formulas assume that there is no loss by friction through the pipes bringing water to the motor, and that the motor itself utilizes all the potential energy in the water ; of course, neither of these assumptions can be strictly true, although the loss from the first cause may, by large pipes, be reduced to a very small quantity.

In the absence of exact knowledge of the efficiency of a motor, we may, in estimating, multiply the value of m above given by two.

RECENT WATER WORKS CONSTRUCTION.

City or Town.	Population.	Supply.		Capacity in million gallons.		Mains.			Cost.	Owned by
		Source.	Mode of	Pump in 24 hrs.	Reservoir.	Material.	Length in Miles.	Sizes.		
Cohasset, Mass...........	3,000	Driven Wells.	P. to R.	¾	1½	Cast I.	6	12 to 4	$75,000	Company.
Calais, Maine.............	6,000	River.	P. to R.	2½	2	Cast I.	16	12 to 4	108,000	Company.
Ware, Mass..............	6,000	Well.	P. to R.	1½	1½	Cast I.	6	12 to 4	72,500	Town.
Waterbury, Conn.........	20,000	Surface.	Gravity.	....	(4) 188	C. L.	....	12 to 4	416,235	City.
Liberty, Va...............	2,500	Surface.	Gravity.	....	....	Cast I.	10	12 to 4	42,000	....
Hyde Park, Mass.........	8,000	Driven Wells.	P. to R.	1½	1½	Cast I.	18	14 to 4	150,000	Company.
Wellsley, Mass...........	2,700	Well.	P. to R.	1	1	Cast I.	13	12 to 4	125,000	Town.
Ann Arbor, Mich.........	10,000	Springs.	P. to R.	....	....	Cast I.	20	....	215,000	Company.
Black River Falls, Wis....	2,500	Ground.	PtoStd.P	1	....	....	....	10 to 4	23 000	City.
Laconia and Lake Village, N. H......	8,500	Lake.	P. to R.	1	....	C. L.	12	12 to 4	84,919	Company.

PART III.

HEAT.

A clear notion of just what that thing is which we call "heat," and of its relation to mechanical work, is essential to any one who would understand and manage intelligently heat engines and heat appliances.

A clear and fascinating exposition of the subject fully illustrated by experiment, is to be found in "Heat a Mode of Motion," by PROF. TYNDALL, Appleton & Co., N. Y., and from this book a few paragraphs are quoted. In the opening chapters Prof. Tyndall sets forth with beautiful clearness the theory, now one of the commonplaces of science, that heat is a form of molecular energy, a mode of motion, and that an increase in temperature in any substance means really an increase in the amount of intermolecular motion.

THE MECHANICAL EQUIVALENT OF HEAT was determined by two independent investigators and by different methods.

Dr. Mayer, a physician in Heilbroun, Germany, thought out in the spring of 1842 the principle involved, and by a calculation so simple as to involve nothing beyond simple proportion, found that the quantity of heat sufficient to raise 1 lb. of water 1° Fahr. in temperature, is competent to raise a weight of 771.4 pounds a foot high.

Dr. Joule, an Englishman, in 1849, applying all the precautions suggested by seven years of experimenting, obtained the following numbers for the mechanical equivalent of heat:

772.692	from	friction of	water,	mean of	40	experiments.
774.083	"	"	" mercury	"	" 50	"
774 987	"	"	" cast iron	"	" 20	"

These experiments rank among the most memorable that have ever been executed in physical science. They form in themselves a strict demonstration of the dynamical theory of heat. For reasons assigned in his paper, Dr. Joule fixes the exact equivalent at

772. foot pounds

and these figures are accepted by the scientific world.

*Recent experiments to determine the value of the Mechanical Equivalent of Heat, made by Messrs Cowper and Anderson, indicate that Dr. Joule's figures are a little too large. These late experiments are described in a paper read before the British Association, and were

* *Engineering News*, Dec., 1887.

conducted on an unusually extensive and perfect scale. In Dr. Joule's apparatus it is probable that all of the heat generated by the falling weight was not utilized in raising the temperature of the fluid, but that part of it was lost by radiation and conduction. As determined by these recent experiments the equivalent is 769 foot lbs.

Latent Heat.

Prof. Tyndall writes: "Let us take the case of ice and trace it through the entire cycle. The block of ice before you has now a temperature of 10° C. below zero. Let us warm it: a thermometer fixed in it rises to zero, and at this point the ice begins to melt; the thermometric column which rose previously, *is now arrested in its march and becomes perfectly stationary.* The wamth is still applied, but there is no augmentation of temperature, and, not until the last film of ice has been removed from the bulb of the thermometer, does the mercury resume its motion.

It is now again ascending; it reaches 30° 60° 100° C.; and here steam bubbles appear in the liquid; it boils, and from this point onward *the thermometer remains stationary at* 100°.

But during the melting of the ice, and during the evaporation of the water, heat is incessantly communicated; to simply liquefy the ice, as much heat is imparted as would raise the same weight of water 79.4° C, or 79.4 times that weight of water one degree in a temperature; and to convert a pound of water at 100 C. into a pound of steam, at the same temperature, 537.2 times as much heat is required, as would raise a pound of water one degree in temperature. The former number 79.4° C. (143°F.) represents what has been hitherto called the latent heat of water; and the latter number 537.2° C. (966° F.) represents the latent heat of steam. * * * * * * According to our present theory, the heat expended in melting is consumed in conferring potential energy upon the atoms.

It is, virtually, the lifting of a weight. So, likewise, as regards steam, the heat is consumed in pulling the liquid molecules asunder, conferring upon them a still greater amount of potential energy. When the heat is withdrawn, the vapor condenses, the molecules again clash with a dynamic energy, equal to that which was employed to separate them, and the precise quantity of heat then consumed reappears.

A Unit of Heat (English) is the quantity required to raise one lb. of water 1° F. in temperature, and its mechanical equivalent has already been given.

A French thermal unit contains nearly 4 English units (exactly 3.968).

Thermometers.

In England and in the United States temperatures are usually measured by the Fahrenheit thermometer, but the more logical arrangement of the centigrade scale has

led scientific investigators to prefer it for their work, and a conversion table will be found useful. The Reaumur thermometer is used in Russia, Sweden, Turkey and Egypt.

	Fahr.	Cent.	Reaumur.
The melting point of ice is	32	0	0
The boiling point of water is	212	100	80

To convert degrees, Centigrade or Reaumur into degrees Fahrenheit.

Let F = No. of degrees Fahrenheit.
C = " " Centigrade.
R = " " Reaumur.

$$F = \frac{9C}{5} + 32 \qquad F = \frac{9R}{4} + 32 \qquad F = C + R + 32$$

$$C = \frac{4\,(F - 32)}{9} \qquad R = \frac{4\,(F - 32)}{9}$$

TABLE FOR THE CONVERSION OF DEGREES OF THE CENTIGRADE THERMOMETER INTO DEGREES OF FAHRENHEIT'S SCALE.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
0	32.	26	78.8	51	123.8	76	168.8
1	33.8	27	80.6	52	125.6	77	170.6
2	35.6	28	82.4	53	127.4	78	172.4
3	37.4	29	84.2	54	129.2	79	174.2
4	39.2	30	86.0	55	131.0	80	176.0
5	41.0	31	87.8	56	132.8	81	177.8
6	42.8	32	89.6	57	134.6	82	179.6
7	44.6	33	91.4	58	136.4	83	181.4
8	46.4	34	93.2	59	138.2	84	183.2
9	48.2	35	95.0	60	140.0	85	185.0
10	50.0	36	96.8	61	141.8	86	186.8
11	51.8	37	98.6	62	143.6	87	188.6
12	53.6	38	100.4	63	145.4	88	190.4
13	55.4	39	102.2	64	147.2	89	192.2
14	57.2	40	104.0	65	149.0	90	194.0
15	59.0	41	105.8	66	150.8	91	195.8
16	60.8	42	107.6	67	152.6	92	197.6
17	62.6	43	109.4	68	154.4	93	199.4
18	64.4	44	111.2	69	156.2	94	201.2
19	66.2	45	113.0	70	158.0	95	203.0
20	68.0	46	114.8	71	159.8	96	204.8
21	69.8	47	116.6	72	161.6	97	206.6
22	71.6	48	118.4	73	163.4	98	208.4
23	73.4	49	120.2	74	165.2	99	210.2
24	75.2	50	122.0	75	167.0	100	212.0
25	77.0						

Water Supply—NICHOLS.

STEAM.

(This paragraph is the opening of the chapter on "Steam" in D. K. Clark's Rules Tables and Data).

When steam is generated in a boiler, the water is heated until it arrives at the temperature of ebullition, and the elevation of temperature is sensible to the thermometer; next, the water is converted into steam by an additional absorption of heat, which is not measured by the thermometer, and is therefore called latent heat. The heat is not, in fact, latent, but is appropriated in converting water into steam, of the same temperature.

The pressure, as well as the density, of steam which is generated over water in a boiler, rises with the temperature and reciprocally the temperature rises with the pressure and density. There is only one pressure and one density for each temperature; and thus it is that steam, produced in a boiler over water, is always generated at the maximum pressure and maximum density corresponding to its temperature.

In such condition steam is said to be saturated, being incapable of vaporizing more water into the same space, unless the the temperature be raised. Saturation is therefore the normal condition of steam generated in contact with a store of water, and the same density and the same pressure are always to be found in conjunction with the same temperature.

In consequence, saturated steam over water stands both at the condensing point and at the generating point; that is, it is condensed if the temperature falls, and more water is evaporated if the temperature rises.

But supposing the whole of the water to be evaporated, or that a body of saturated steam is isolated from water, in a space of fixed dimensions, if an additional quantity of heat be supplied to the steam, the state of saturation ceases, the steam becomes super-heated, and the temperature and the pressure are increased, whilst the density is not increased. Steam thus surcharged with heat, approaches to the condition of a perfect gas.

SPECIFIC HEAT. (D. K. Clarke.)

The specific heat of a body signifies its capacity for heat, or the quantity of heat required to raise the temperature of the body one degree Fahrenheit, compared with that required to raise the temperature of a quantity of water of equal weight one degree. The British unit of heat is that which is required to raise the

temperature of one pound of water one degree, from 32° to 33° F.; and the specific heat of another body is expressed by the quantity of heat, in units, necessary to raise the temperature of one pound weight of such body one degree.

The specific heat of water at 32° F. is represented by 1 or unity, and as there are very few bodies whose temperature cannot be raised one degree by the expenditure of less heat than would be required to raise the temperature of an equal weight of water one degree, specific heats of bodies are, therefore, almost universally expressible by fractions of a unit.

Table of Specific Heat.

Water = 1.

Bismuth	.03084
Lead	.0314
Platinum	.0335
Mercury	.0333
Gold	.0324
Antimony	.0507
Tin	.0569
Silver	.0570
Brass	.09391
Copper	.0951
Zinc	.0955
Wrought Iron	.1098
Steel, soft	.1165
Cast Iron, white	.1298

EVAPORATION IN BOILERS.

Evaporative tests may be made with feed water varying from 60° to above 212°, and under steam pressures varying from 25 to 200 lbs. per sq. in., but for purposes of comparison it is convenient to reduce the results obtained to equivalent evaporation at and from 212°. The reason for choosing this basis of comparison becomes apparent when we reflect that it is under these conditions, namely with feed water at 212°, and with no pressure but that of the atmosphere, that a boiler will evaporate the largest quantity of water with a given quantity of heat.

In preceding pages we have noted that 966 units of heat are required to evaporate a pound of water into steam at and from 212°, and we now may add that under any known *working* conditions of pressure of steam and temperature of feed a somewhat larger amount will be

required—just how much larger will depend upon the efficiency of the boiler, and the temperature and pressure.

Rankine says, "The total heat of steam from the temperature of melting ice increases at a uniform rate as the temperature of evaporation rises," and the law is expressed by the formula

$$h = 1091.7 + 0.305\ (T - 32^{\circ})$$

in which h = the total heat required to generate steam at a given temperature T, starting with water at 32°.

The total heat expended h_2 in evaporating from a temperature T_2 and at a temperature T_1 is expressed by Rankin thus:—

$$h_2 = 1092 + 0.3\ (T_1 - 32) - (T_2 - 32)$$

If a = pounds of water evaporated from T_2 and at T_1 then

$$a \frac{h_2}{966} = \text{pounds from and at } 212^{\circ}.$$

The expression $\frac{h_2}{966}$ is called the factor o. evaporation.

The number of heat units required to evaporate under any given condition may be obtained by this formula and the use of tables, but as a labor saving device we offer the following table of factors of evaporation taken from "Steam Making or Boiler Practice," by the late CHAS. A. SMITH, C.E.; published by the *American Engineer*, Chicago, Ill.

For example, if we have found by actual trial that a boiler evaporates 9¼ lbs. of water per pound of coal with feed at 90° and steam of 80 lbs. pressure, and will look in the table at the junction of the 90 horizontal line and 80 vertical column, we shall find the factor 1.162, and if we multiply 9¼ by this factor we shall have the equivalent evaporation at and from 212°, or 10¾ pounds, nearly.

TEMPERATURE OF FEED-WATER IN DEGREES FAHR.	PRESSURE IN POUNDS PER SQUARE INCH ABOVE THE ATMOSPHERE.																				
	0	5	10	15	20	25	30	35	40	45	50	60	70	80	90	100	120	140	160	180	200
32	1.187	1.192	1.195	1.199	1.201	1.204	1.206	1.209	1.211	1.212	1.214	1.217	1.219	1.222	1.224	1.227	1.231	1.234	1.237	1.239	1.241
35	1.184	1.189	1.102	1.196	1.198	1.201	1.203	1.206	1.208	1.209	1.211	1.214	1.216	1.219	1.221	1.224	1.228	1.231	1.234	1.236	1.238
40	1.179	1.184	1.187	1.191	1.193	1.196	1.198	1.201	1.203	1.204	1.206	1.209	1.211	1.214	1.216	1.219	1.223	1.226	1.229	1.231	1.233
45	1.173	1.178	1.181	1.185	1.187	1.190	1.192	1.195	1.197	1.198	1.200	1.203	1.205	1.208	1.210	1.213	1.217	1.220	1.223	1.225	1.227
50	1.168	1.173	1.177	1.180	1.182	1.185	1.187	1.190	1.192	1.193	1.195	1.198	1.200	1.203	1.205	1.208	1.212	1.215	1.218	1.220	1.222
55	1.163	1.168	1.171	1.175	1.177	1.180	1.182	1.185	1.187	1.188	1.190	1.193	1.195	1.198	1.200	1.203	1.207	1.210	1.213	1.215	1.217
60	1.158	1.163	1.166	1.170	1.172	1.175	1.177	1.180	1.182	1.183	1.185	1.188	1.190	1.193	1.195	1.198	1.202	1.205	1.208	1.210	1.212
65	1.153	1.158	1.161	1.165	1.167	1.170	1.172	1.175	1.177	1.178	1.180	1.183	1.185	1.188	1.190	1.193	1.197	1.200	1.203	1.205	1.207
70	1.148	1.153	1.156	1.160	1.162	1.165	1.167	1.170	1.172	1.173	1.175	1.178	1.180	1.183	1.185	1.188	1.192	1.195	1.198	1.200	1.202
75	1.143	1.148	1.151	1.155	1.157	1.160	1.162	1.165	1.167	1.168	1.170	1.173	1.175	1.178	1.180	1.183	1.187	1.190	1.193	1.195	1.197
80	1.137	1.143	1.146	1.149	1.151	1.154	1.156	1.159	1.161	1.162	1.164	1.167	1.169	1.172	1.174	1.177	1.181	1.184	1.187	1.189	1.191
85	1.132	1.137	1.140	1.144	1.146	1.149	1.151	1.154	1.156	1.157	1.159	1.162	1.164	1.167	1.169	1.172	1.176	1.179	1.182	1.184	1.186
90	1.127	1.132	1.135	1.139	1.141	1.144	1.146	1.149	1.151	1.152	1.154	1.157	1.159	1.162	1.164	1.167	1.171	1.174	1.177	1.179	1.181
95	1.122	1.127	1.130	1.134	1.136	1.139	1.141	1.144	1.146	1.147	1.149	1.152	1.154	1.157	1.159	1.162	1.166	1.169	1.172	1.174	1.176
100	1.117	1.122	1.125	1.129	1.131	1.134	1.136	1.139	1.141	1.142	1.144	1.147	1.149	1.152	1.154	1.157	1.161	1.164	1.167	1.169	1.171
105	1.111	1.117	1.120	1.123	1.125	1.128	1.130	1.133	1.135	1.136	1.133	1.141	1.143	1.146	1.148	1.151	1.155	1.158	1.161	1.163	1.165
110	1.106	1.111	1.114	1.118	1.120	1.123	1.125	1.128	1.130	1.131	1.133	1.136	1.138	1.141	1.143	1.146	1.150	1.153	1.156	1.158	1.160
115	1.101	1.106	1.109	1.113	1.115	1.118	1.120	1.123	1.125	1.126	1.120	1.131	1.133	1.136	1.138	1.141	1.145	1.148	1.151	1.153	1.155
120	1.096	1.101	1.104	1.108	1.110	1.113	1.115	1.118	1.120	1.121	1.123	1.126	1.128	1.131	1.133	1.136	1.140	1.143	1.146	1.148	1.150
125	1.091	1.096	1.099	1.103	1.105	1.108	1.110	1.113	1.115	1.116	1.118	1.121	1.123	1.126	1.128	1.131	1.135	1.138	1.141	1.143	1.145
130	1.085	1.091	1.094	1.097	1.099	1.102	1.104	1.107	1.109	1.110	1.112	1.115	1.117	1.120	1.122	1.125	1.129	1.132	1.135	1.137	1.139
135	1.080	1.085	1.088	1.092	1.094	1.097	1.099	1.102	1.104	1.105	1.107	1.110	1.112	1.115	1.117	1.120	1.124	1.127	1.130	1.132	1.134
140	1.075	1.080	1.083	1.087	1.089	1.092	1.094	1.097	1.099	1.100	1.102	1.105	1.107	1.110	1.112	1.115	1.119	1.122	1.125	1.127	1.129
145	1.070	1.075	1.078	1.082	1.084	1.087	1.089	1.092	1.094	1.095	1.097	1.100	1.102	1.105	1.107	1.110	1.114	1.117	1.120	1.122	1.124
150	1.065	1.070	1.173	1.077	1.079	1.082	1.084	1.087	1.089	1.090	1.092	1.095	1.097	1.100	1.102	1.105	1.109	1.112	1.115	1.117	1.119
155	1.059	1.065	1.068	1.071	1.073	1.076	1.078	1.081	1.083	1.084	1.086	1.089	1.091	1.094	1.096	1.099	1.103	1.106	1.109	1.111	1.113
160	1.054	1.059	1.062	1.066	1.068	1.071	1.073	1.076	1.078	1.079	1.081	1.084	1.086	1.089	1.091	1.094	1.098	1.101	1.104	1.106	1.108
165	1.049	1.054	1.157	1.061	1.063	1.066	1.068	1.071	1.073	1.074	1.076	1.079	1.081	1.084	1.086	1.089	1.093	1.096	1.099	1.101	1.103
170	1.044	1.049	1.052	1.056	1.058	1.061	1.063	1.066	1.068	1.069	1.071	1.074	1.076	1.079	1.081	1.084	1.088	1.091	1.094	1.096	1.098
175	1.039	1.044	1.047	1.051	1.053	1.056	1.058	1.061	1.063	1.064	1.066	1.069	1.071	1.074	1.076	1.079	1.083	1.086	1.089	1.091	1.093
180	1.033	1.039	1.042	1.045	1.047	1.050	1.052	1.055	1.057	1.058	1.060	1.063	1.065	1.068	1.070	1.073	1.077	1.080	1.083	1.085	1.087
185	1.028	1.033	1.036	1.040	1.042	1.045	1.047	1.050	1.052	1.053	1.055	1.058	1.060	1.063	1.065	1.068	1.072	1.075	1.078	1.080	1.082
190	1.023	1.028	1.031	1.035	1.037	1.040	1.042	1.045	1.047	1.048	1.050	1.053	1.055	1.058	1.060	1.063	1.067	1.070	1.073	1.075	1.077
195	1.018	1.023	1.025	1.030	1.032	1.035	1.037	1.040	1.042	1.043	1.045	1.048	1.050	1.053	1.055	1.058	1.062	1.065	1.068	1.070	1.072
200	1.013	1.018	1.021	1.025	1.027	1.030	1.032	1.035	1.037	1.038	1.040	1.043	1.045	1.048	1.050	1.053	1.057	1.060	1.063	1.065	1.067
205	1.008	1.013	1.015	1.020	1.022	1.025	1.027	1.030	1.032	1.033	1.035	1.038	1.040	1.043	1.045	1.048	1.052	1.055	1.058	1.060	1.062
210	1.008	1.008	1.011	1.015	1.017	1.020	1.022	1.025	1.027	1.028	1.030	1.033	1.035	1.038	1.040	1.043	1.047	1.050	1.053	1.055	1.057
212	1.002	1.002																			

For a more elaborate set of Tables upon this topic, we refer with especial pleasure to "Tables for facilitating calculations of Boiler Tests" by WM. KENT, M. E., New York, reprinted from Vol. VI, "Transactions of the American Society of Mechanical Engineers," from which the following table is taken.

Heat Units in water, between 32° and 212° F. (reckoned from 32° F.) and weight of water per cubic foot.

Temperature.	Heat Units.	Weight, lbs. per cubic foot.	Temperature.	Heat Units.	Weight, lbs. per cubic foot.	Temperature.	Heat Units.	Weight, lbs. per cubic foot.
32°F.	0.	62.42	93°F.	61.06	62.10	154°F.	122.33	61.10
33	1.	62.42	94	62.06	62.09	155	123.34	61.08
34	2.	62.42	95	63.07	62.08	156	124.35	61.06
35	3.	62.42	96	64.07	62.07	157	125.35	61.04
36	4.	62.42	97	65.07	62.06	158	126.36	61.02
37	5.	62.42	98	66.07	62.05	159	127.37	61.00
38	6.	62.42	99	67.08	62.03	160	128.37	60.98
39	7.	62.42	100	68.08	62.02	161	129.38	60.96
40	8.	62.42	101	69.08	62.01	162	130.39	60.94
41	9.	62.42	102	70.09	62.00	163	131.40	60.92
42	10.	62.42	103	71.09	61.99	164	132.41	60.90
43	11.	62.42	104	72.09	61.97	165	133.41	60.87
44	12.	62.42	105	73.10	61.96	166	134.42	60.85
45	13.	62.42	106	74.10	61.95	167	135.43	60.83
46	14.	62.42	107	75.10	61.93	168	136.44	60.81
47	15.	62.42	108	76.10	61.92	169	137.45	60.79
48	16.	62.41	109	77.11	61.91	170	138.45	60.77
49	17.	62.41	110	78.11	61.89	171	139.46	60.75
50	18.	62.41	111	79.11	61.88	172	140.47	60.73
51	19.	62.41	112	80.12	61.86	173	141.48	60.70
52	20.	62.40	113	81.12	61.85	174	142.49	60.68
53	21.01	62.40	114	82.13	61.83	175	143.50	60.66
54	22.01	62.40	115	83.13	61.82	176	144.51	60.64
55	23.01	62.39	116	84.13	61.80	177	145.52	60.62
56	24.01	62.39	117	85.14	61.78	178	146.52	60.59
57	25.01	62.39	118	86.14	61.77	179	147.53	60.57
58	26.01	62.38	119	87.15	61.75	180	148.54	60.55
59	27.01	62.38	120	88.15	61.74	181	149.55	60.53
60	28.01	62.37	121	89.15	61.72	182	150.56	60.50
61	29.01	62.37	122	90.16	61.70	183	151.57	60.48
62	30.01	62.36	123	91.16	61.68	184	152.58	60.46
63	31.01	62.36	124	92.17	61.67	185	153.59	60.44
64	32.01	62.35	125	93.17	61.65	186	154.60	60.41
65	33.01	62.34	126	94.17	61.63	187	155.61	60.39
66	34.02	62.34	127	95.18	61.61	188	156.62	60.37
67	35.02	62.33	128	96.18	61.60	189	157.63	60.34
68	36.02	62.33	129	97.19	61.58	190	158.64	60.32
69	37.02	62.32	130	98.19	61.56	191	159.65	60.29
70	38.02	62.31	131	99.20	61.54	192	160.67	60.27
71	39.02	62.31	132	100.20	61.52	193	161.68	60.25
72	40.02	62.30	133	101.21	61.51	194	162.69	60.22
73	41.02	62.29	134	102.21	61.49	195	163.70	60.20
74	42.03	62.28	135	103.22	61.47	196	164.71	60.17
75	43.03	62.28	136	104.22	61.45	197	165.72	60.15
76	44.03	62.27	137	105.23	61.43	198	166.73	60.12
77	45.03	62.26	138	106.23	61.41	199	167.74	60.10
78	46.03	62.25	139	107.24	61.39	200	168.75	60.07
79	47.03	62.24	140	108.25	61.37	201	169.77	60.05
80	48.04	62.23	141	109.25	61.36	202	170.78	60.02
81	49.04	62.22	142	110.26	61.34	203	171.79	60.00
82	50.04	62.21	143	111.26	61.32	204	172.80	59.97
83	51.04	62.20	144	112.27	61.30	205	173.81	59.95
84	52.04	62.19	145	113.28	61.28	206	174.83	59.92
85	53.05	62.18	146	114.28	61.26	207	175.84	59.89
86	54.05	62.17	147	115.29	61.24	208	176.85	59.87
87	55.05	62.16	148	116.29	61.22	209	177.86	59.84
88	56.05	62.15	149	117.30	61.20	210	178.87	59.82
89	57.05	62.14	150	118.31	61.18	211	179.89	59.79
90	58.06	62.13	151	119.31	61.16	212	180.90	59.76
91	59.06	62.12	152	120.32	61.14			
92	60.06	62.11	153	121.33	61.12			

Total Heat Units in Water and Steam.

(Reckoned above 32° Fahrenheit)

Gauge Pressure lb. per square inch.	Absolute Pressure lbs. per square inch.	Temperature Fahr. °	Heat Units in Steam. *H.*	Heat Units in Water. *h.*	Latent Heat of Evaporation. *H—h.*
0.	14.696	212.00	1146.60	180.90	965.70
0.304	15	213.03	1146.91	181.94	964.97
1 +	16	216.30	1147.91	185.25	962.66
5 +	20	227.92	1151.45	197.04	954.41
10 +	25	240.00	1155.14	209.31	945.83
15 +	30	250.25	1158.26	219.74	938.52
20 +	35	259.18	1160.99	228.84	932.15
25 +	40	267.12	1163.41	236.94	926.47
30 +	45	274.30	1165.60	244.27	921.33
35 +	50	280.85	1167.60	250.97	916.63
40 +	55	286.90	1169.44	257.15	912.29
42 +	57	289.11	1170.14	259.50	910.64

The vapor arising from water, at its boiling point, called steam—is a chemical compound—8 parts, by weight, of oxygen to 1 of hydrogen. Steam proper is perfectly transparent and colorless, dry, and only moist when condensed; wholly invisible, and when apparent, only so by reason of partial condensation.

Its density is equal to pressure of the atmosphere, or 14.72 lbs. per square inch, and, unless confined, the temperature of water cannot be raised above the boiling-point.

One cubic inch of water evaporated, under ordinary pressure of atmosphere, is converted into about 1,700 cubic inches of steam, or nearly 1 cubic foot; it exerts a mechanical force equal to raising 2120.14 lbs. 1 foot high.

26.36 cu. ft. of steam at atmospheric pressure weighs 1 lb. avoirdupois; 1 lb. of water, heated from 32° to 212°, requires as much heat as would raise 180 lbs 1°.

One lb. of water at 212° converted into steam at 212° atmospheric pressure, absorbs as much heat for its conversion as will raise 966 lbs. of water 1°.

Pressure of 1 lb. per square inch will support a column of mercury (60° F.) 2.0376 inches; therefore in a syphon gauge (U), one-half of this, or 1.0188 inches.

HORSE POWER OF BOILERS.

The following letter kindly written in response to an inquiry by the compiler, puts this subject in a very clear light.

STEVENS INSTITUTE OF TECHNOLOGY.
HOBOKEN, N.J., Oct., 1883.

Dear Sir:—In reply to yours of 15th. inst.,—the unit of horse power for boilers is not fixed except by arbitrary agreement among parties concerned, the basis differing according to the nature of work to be done by the steam; to illustrate:—

1. If a boiler is tested, and a statement of its horse power desired without regard to whether it is to supply its steam to drive an engine, or to heat a building, or to boil clothes in a dye house—then it is agreed among the majority of experts of the United States to consider 30 lbs. per hour of steam at any pressure in the neighborhood of 70 lbs. as a horse power. And a 100 horse power boiler would be one that evaporated 3000 lbs. of water in an hour under about 70 lbs. pressure, the water being fed into the boiler at 200° Fahrenheit.

2. If a certain engine is to be supplied with a boiler on the understanding that the boiler is to enable the engine to develop 100 horse power, the horse power of the boiler must be measured by the weight of steam which the engine will use per hour in developing each of its 100 horse powers. If the engine be an ordinary slide valve engine with fixed cut-off, about 45 lbs of steam will be used each hour for each horse power developed by engine; accordingly, the boiler would have to deliver 45 lbs. of steam per hour for each horse power or 4500 lbs. of steam per hour for 100 horse power. Consequently, if the boiler had been tested and rated at 100 horse power on the 30 lbs. basis as explained in paragraph (1), it would supply only $\frac{3000}{4500}$ x 100, or 66 horse power with such an engine, and it could only be regarded as a 66 horse power boiler.

3. On the other hand, if the engine was an automatic cut-off engine with all the refinements of economic workings, it could develop each of its horse power with a consumption of only 20 lbs. of steam per hour, or a hundred horse power with 2000 lbs. of steam per hour, in which case the boiler of paragraph (1) could supply the engine with $\frac{3000}{2000}$ x 100, or 150 horse power.

The amount of steam that different types of engines use in an hour for each horse power that they develop can not be calculated with exactness. It is only known, without testing the engine, by the exercise of good judgment through comparison of the conditions under which the engine operates with those of some other engine (as similar can be found) which has been tested.

It is because of this variation of the amount of steam used in different engines in developing a horse power, that a necessity for some arbitrary figure to be agreed upon by experts is experienced, and in selecting 30 lbs. as explained in paragraph (1), a fair average between the very best and the quite uneconomic engine performance is taken. This does not, however, alter the fact that we cannot state the horse power of a boiler independently of the kind of engine to be driven.

4. For heating purposes the horse power of a boiler is measured by the cubic feet of space it will heat; the cubic feet of space is given a radiating surface in the proportion of 1 sq. ft. of radiating surface to about 100 cubic feet of space, and the boiler is given heating surface in the proportion of 12 sq. ft. of radiating surface to 1 sq. ft. of heating surface in the boiler, assuming that each square foot of the latter can evaporate 3 lbs. of steam per hour at about 70 lbs. pressure; and finally, the boiler maker sells the boiler on the assumption that each 15 sq. ft. of heating surface is a horse power, which, evidently, is equivalent to $15 \times 3 = 45$ lbs. of steam for a horse power.

For steam heating practice, therefore, a 100 horse power boiler is practically expected to be one that will evaporate 4500 lbs. of water per hour, and should a boiler be tested and rated at 100 horse power on the 30 lbs. basis (as explained in paragraph 1), independently of the kind of work it was to do, that boiler if used for steam heating, might fail to heat as large a space as steam heaters had been accustomed to heat with a 100 horse power boiler, and had there been no agreement as to what should constitute the basis of horse power for the boiler, the steam heater would be justified in calling the boiler (of paragraph 1) a $\frac{3000}{4500}$ $100 = 66$ horse power boiler, instead of a 100 horse power.

After the above manner each department of practice in which boilers are used has its own measure of horse

power, which really means a certain number of pounds of steam to be delivered per hour by each horse power claimed for a boiler; hence the only fixed element about the horse power of a boiler for all purposes, is the number of pounds of steam the boiler will evaporate in an hour—this being known either by test of the boiler, or judicious estimate by experienced judges.

Consistent application of the term horse power to a boiler, requires that the latter should be regarded as capable of giving as many horse power as is represented by the quotient obtained by dividing the number of pounds of steam which the boiler can evaporate per hour, by the number of pounds of steam which, in the particular path of practise to which the boiler is devoted, has been decided to be requisite for the production of a horse power of useful effect.

Should you have any special case in mind in making the inquiry, by giving us the facts, we could reply more definitely. Yours truly,

JAS. E. DENTON, M.E.,
Prof. of Experimental Mechanics.

A gallon of water (U. S. standard) weighs 8 1-3 lbs., and contains 231 cubic inches.

A cubic foot of water weighs 62½ lbs., and contains 1,728 cubic inches, or 7½ gallons.

Each *nominal* horse power of boilers requires 1 cubic foot of water per hour.

In calculating horse power of steam boilers, consider for—

Tubular boilers 15 sq. ft. of heating surface equivalent to 1 horse power.

Flue boilers 12 sq. ft. of heating surface equivalent to 1 horse power.

Cylinder boilers 10 sq. ft. of heating surface equivalent to 1 horse power.

To find the area of a piston, square the diameter and multiply by .7854.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

Elastic Force of Steam, and Corresponding Temperature of the Water with which it is in Contact.

Pressure on a Square Inch.	Elastic Force in Inches of Mercury.	Temperature in Degrees of Fahrenheit.	Volume of Steam compared with the Volume of Water.	Pressure on a Square Inch.	Elastic Force in Inches of Mercury.	Temperature in Degrees of Fahrenheit.	Volume of Steam compared with the Volume of Water.
lbs.				lbs.			
14.7	30.00	212.0	1700	56	114.24	290.5	500
15	30.60	212.8	1669	57	116.28	291.7	492
16	32.64	216.3	1573	58	118.32	292.9	484
17	34.68	219.6	1488	59	120.36	294.2	477
18	36.72	222.7	1411	60	122.40	295.6	470
19	38.76	225.6	1343	61	124.44	296.9	463
20	40.80	228.5	1281	62	126.48	298.1	456
21	42.84	231.2	1225	63	128.52	299.2	449
22	44.88	233.8	1174	64	130.56	300.3	443
23	46.92	236.3	1127	65	132.60	301.3	437
24	48.96	238.7	1084	66	134.64	302.4	431
25	51.00	241.0	1044	67	136.68	303.4	425
26	53.04	243.3	1007	68	138.72	304.4	419
27	55.08	245.5	973	69	140.76	305.4	414
28	57.12	247.6	941	70	142.80	306.4	408
29	59.16	249.6	911	71	144.84	307.4	403
30	61.21	251.6	883	72	146.88	308.4	398
31	63.24	253.6	857	73	148.92	309.3	393
32	65.28	255.5	833	74	150.96	310.3	388
33	67.32	257.3	810	75	153.02	311.2	383
34	69.36	259.1	788	76	155.06	312.2	379
35	71.40	260.9	767	77	157.10	313.1	374
36	73.44	262.6	748	78	159.14	314.0	370
37	75.48	264.3	729	79	161.18	314.9	366
38	77.52	265.9	712	80	163.22	315.8	362
39	79.56	267.5	695	82	167.30	317.6	354
40	81.60	269.1	679	84	171.38	319.3	346
41	83.64	270.6	664	86	175.46	321.0	339
42	85.68	272.1	649	88	179.54	322.6	332
43	87.72	273.6	635	90	183.62	324.3	325
44	89.76	275.0	622	95	193.82	328.2	310
45	91.80	276.4	610	100	204.01	332.0	295
46	93.84	277.8	598	110	224.40	339.2	271
47	95.88	279.2	586	120	244.82	345.8	251
48	97.92	280.5	575	130	265.23	352.1	233
49	99.96	281.9	564	140	285.61	357.9	218
50	102.00	283.2	554	150	306.03	363.4	205
51	104.04	284.4	544	160	326.42	368.7	193
52	106.08	285.7	534	170	346.80	373.6	183
53	108.12	286.9	525	180	367.25	378.4	174
54	110.16	288.1	516	190	387.61	382.9	166
55	112.20	289.3	508	200	408.04	387.3	158

is measured by an arbitrary unit of "horse power," which is measured by 33,000 pounds raised one foot high in one minute, and in mill and shop engines the efficiency of the prime motor is measured by the quantity of coal or steam consumed per horse power per hour. Wasteful and badly managed engines will show a consumption of 6 pounds—ordinary cases give 3 pounds, while the best practise is not satisfied with anything larger than 1.75 pounds of coal per horse power per hour.

Pumping engines are rated for efficiency according to the "duty" given, that is, according to the number of pounds (of water) lifted one foot high with 100 pounds of coal. These two standards are different, but are convertible; for example, D. K. Clark gives—

$$\left.\begin{array}{l}\text{1,000,000, foot pounds}\\ \text{per lb. of fuel}\end{array}\right\} = \left\{\begin{array}{l}\text{1.98 lbs. of fuel per horse}\\ \text{power per hour.}\end{array}\right.$$

These figures given by Clark are strictly true as a scientific statement, but as Jack Bunsby says, "the bearin' of this 'ere observation lies in the application of it," and the above figures cannot be applied to ordinary working cases without a check, and for the following reason. In the best of pumping engines the power shown in the water lifted does not equal the full power developed by the engine, because some power is required to overcome friction and inertia. The following table prepared by Mr. Wm. B. Sherman, C. E., of Providence, R. I., and forming part of a paper on pumping engines read by him before the American Water Works Association, in April, 1885, is computed for pumping engines in which 90 per cent. of the power indicated at the steam end, reappears in useful work at the water end.

Table showing Amount of Coal Required to Raise One Million Gallons of Water in 24 Hours to a Height of 200 Feet—the Corresponding Duty and Quantity of Fuel per Hour per Horse Power.

Duty.	Lbs. Coal per Million Gallons.	Lbs. Coal per Hour per H. P.	Duty.	Lbs. Coal per Million Gallons.	Lbs. Coal per Hour per H. P.	Duty.	Lbs. Coal per Million Gallons.	Lbs. Coal per Hour per H. P.	Duty.	Lbs. Coal per Million Gallons.	Lbs. Coal per Hour per H. P.
30	5560	5.94	51	3271	3.49	71	2349	2.51	91	1833	1.96
31	5380	5.75	52	3208	3.43	72	2317	2.48	92	1813	1.94
32	5212	5.57	53	3147	3.36	73	2285	2.44	93	1793	1.92
33	5054	5.40	54	3089	3.30	74	2254	2.41	94	1774	1.90
34	4906	5.24	55	3033	3.24	75	2224	2.38	95	1756	1.88
35	4766	5.09	56	2979	3.18	76	2195	2.35	96	1738	1.86
36	4634	4.95	57	2926	3.13	77	2166	2.31	97	1720	1.84
37	4508	4.82	58	2876	3.07	78	2138	2.28	98	1702	1.82
38	4390	4.69	59	2827	3.02	79	2111	2.26	99	1685	1.80
39	4276	4.57	60	2780	2.97	80	2085	2.23	100	1668	1.78
40	4170	4.45	61	2734	2.92	81	2059	2.20	101	1651	1.76
41	4068	4.35	62	2690	2.87	82	2034	2.17	102	1635	1.75
42	3972	4.24	63	2648	2.83	83	2009	2.15	103	1619	1.73
43	3880	4.14	64	2606	2.78	84	1985	2.12	104	1604	1.71
44	3790	4.05	65	2566	2.74	85	1962	2.10	105	1589	1.70
45	3707	3.95	66	2527	2.70	86	1940	2.07	106	1573	1.68
46	3626	3.87	67	2490	2.66	87	1917	2.05	107	1559	1.67
47	3549	3.79	68	2453	2.62	88	1895	2.02	108	1544	1.65
48	3475	3.71	69	2417	2.58	89	1874	2.00	109	1530	1.63
49	3404	3.63	70	2383	2.55	90	1853	1.98	110	1516	1.62
50	3336	3.56	......	......	......	......	......	......	......	......	......

The "Duty" of Pumping Engines

is an expression whose essential elements are well understood, nor is there serious disagreement as to the main features of the method to be followed in the determination of its value. Strictly comparable results, are, however, not always easy to obtain because of differences in detail which are found when methods of computation and arrangement are analyzed. It so often happens that pumping engines represent some portion of invested capital upon which returns are expected, that it would seem as though the commercial aspect of the case should govern us in an endeavor to fix a standard formula for the value of duty, and this thought is predominant in the formula suggested by the N. E. W. W. Association, which is

$$\text{Duty} = \frac{\text{Galls. pumped in 1 year} \times 8.34 \times \text{total lift} \times 100}{\text{Total coal burned in year.}}$$

Special trials and "fancy figuring" will give a higher duty than the above work-a-day rule, and in certain cases, special trials will have positive scientific value, but for the investor, the homely rule is to be preferred.

TABLE OF SIZES OF CHIMNEYS.

BY WILLIAM KENT, M.E., NEW YORK.

The accompanying table of sizes of chimneys for various horse powers of boilers is based on the following data:

1. The draught power of the chimney varies as the square root of the height.

2. The retarding of the ascending gases by friction may be considered as equivalent to a diminution of the area of the chimney, or to a lining of the chimney by a layer of gas which has no velocity. The thickness of this lining is assumed to be two inches for all chimneys, or the diminution of area equal to the perimeter x two inches (neglecting the overlapping of the corners of the lining). Expressed algebraically, let D = diameter, A = area, E = effective area.

For square chimneys, $E = D^2 - \frac{8D}{12} = A - \frac{2\sqrt{A}}{3}$

For round chimneys, $E = \pi\left(D^2 - \frac{8D}{12}\right) = A - 0.592\sqrt{A}$

For simplifying calculations, the coefficient of $\sqrt{A}$ may be taken as 0.6 for both square and round chimneys, and the formula becomes

$$E = A - 0.6\sqrt{A}.$$

3. The power varies directly as this effective area E.

4. A chimney 80′ high, 42″ diameter, has been found to be sufficient to cause a rate of combustion of 120 pounds of coal per hour per square foot of area of chimney, or, if the grate area is to the chimney area as 8 to 1, a combustion of 15 pounds of coal per square foot of grate per hour. This is fair practise for a boiler of modern type, in which flues, or tubes, are of moderate diameter, gas passages circuitous, and heating surface extensive in proportion to rate of combustion, so as to cool the chimney gases to 400° or 500°, and produce high economy.

5. A chimney should be proportioned so as to be capable of giving sufficient draught to cause the boiler to develop much more than its rated power, in case of emergencies, or to cause the combustion of 5 pounds of fuel per rated horse power of boiler per hour.

Conditions 4 and 5 being assumed, the $80' \times 42''$ chimney, 9.62 square feet area, will cause the combustion of $9.62 \times 120 = 1154.4$ pounds of coal per hour, or at 5 pounds of coal per horse power per hour, is rightly proportioned for 231 horse power of boilers.

The power of the chimney varying directly as the effective area, E, and as the square root of the height, h, the formula for horse power of boiler for a given size of chimney will take the form,—

$$\text{HP.} = CE\sqrt{h}, \text{ in which } C \text{ is a constant.}$$

For the $80' \times 42''$ chimney,—

$$E = A - 0.6\sqrt{A} = 7.76 \text{ square feet.}$$
$$\sqrt{h} = 8.944 \text{ feet.}$$

Substituting these values in the formula it becomes,—

$$231 = C \times 7.76 \times 8.944,$$
$$\text{whence } C = 3.33,$$

and the formula for horse power is

$$\text{HP.} = 3.33\, E\sqrt{h}, \text{ or, } \text{HP.} = 3.33\,(A - .6\sqrt{A})\sqrt{h}.$$

If the horse power of boiler is given, to find the size of chimney, the height being assumed,

$$E = \frac{0.3 \text{ HP.}}{\sqrt{h}}$$

For round chimneys,—Diameter of chimney = Diam. of $E + 4''$.

For square chimneys, Side of chimney $= \sqrt{E} + 4''$.

In the formulæ and table no account has been taken of the difference which is believed by some authorities to exist in the efficiencies of round and square chimneys of equal area, nor of the differences of friction and of rate of cooling of the gases in iron and in brick chimneys. Should experimental data of these differences, or of the effect of infiltration of air into brick chimneys, be obtained in future, the formulæ and table may be corrected accordingly.

SIZES OF CHIMNEYS FOR STEAM BOILERS.

Formula, $HP. = 3.33 (A - 0.6 \sqrt{A}) \sqrt{h}$.

Diam. inches.	Area A. sq. ft.	Effective Area. $E = A - 0.6\sqrt{A}$. sq. ft.	HEIGHT OF CHIMNEY. 50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft.	Equivalent Square Chimney. Side of square $\sqrt{E} + 4$ inches.
			COMMERCIAL HORSE POWER OF BOILER.											
18	1.77	.97	23	25	27	...	...	...	....	....	....	....	....	16
21	2.41	1.47	35	33	41	...	...	...	....	....	....	....	....	19
24	3.14	2.08	49	54	58	62	...	...	....	....	....	....	....	22
27	3.98	2.78	65	72	78	83	...	...	....	....	....	....	....	24
30	4.91	3.58	84	92	100	107	113	...	....	....	....	....	....	27
33	5.94	4.48	..	115	125	133	141	...	....	....	....	....	....	30
36	7.07	5.47	..	141	152	163	173	182	....	....	....	....	....	32
39	8.30	6.57	..	...	183	196	208	219	....	....	....	....	....	35
42	9.62	7.76	..	...	216	231	245	258	271	....	....	....	....	38
48	12.57	10.44	..	...	...	311	330	348	365	389	....	....	....	43
54	15.90	13.51	..	...	...	...	427	449	472	503	551	....	....	48
60	19.64	16.98	..	...	...	...	536	565	593	632	692	748	....	54
66	23.76	20.83	..	...	...	...	...	694	728	776	849	918	981	59
72	28.27	25.08	..	...	...	...	...	835	876	934	1023	1105	1181	64
78	33.18	29.73	..	...	...	...	...	...	1038	1107	1212	1310	1400	70
84	38.48	34.76	..	...	...	...	...	...	1214	1294	1418	1531	1637	75
90	44.18	40.19	..	...	...	...	...	...	....	1496	1639	1770	1893	80
96	50.27	46.01	..	...	...	...	...	...	....	....	1876	2027	2167	86

VENTILATION. (F. Schumann.)

Proper velocity of currents, in feet, per second.

When entering at or near the ceiling and descending, 1.8 ft.

When entering at or near the ceiling and horizontal, 4.0 ft, (when the openings are not less than 12 feet above the floor.)

When entering at or near the floor, maximum 2.0 ft.
In ducts, shafts, etc., 3 to 10.0 ft.

Loss of heat in ventilated rooms is caused by:—

1st. Units of heat required to warm the air passing through the room.
2nd. Units of heat absorbed by surrounding walls.
3rd. Units of heat absorbed by ceiling.
4th. Units of heat absorbed by floor.
5th. Units of heat absorbed by windows.

Sources of heat in rooms are:—

1st. Units of heat generated by the occupants.
2nd. Units of heat generated by gas, oil, or candles.
3rd. Units of heat generated by the heating apparatus.

In round numbers:

An adult man vitiates per hour .	215.	cu. ft. of air
Every cubic foot of gas burned .	8.5	" " "
Every pound of oil burned .	150.	" " "
Every pound of candles, 6 to 1 lb.	160.	" " "

Units of heat generated by one adult per hour	191
" " " " " cubic foot of gas	600
" " " " " pound of oil or candles	15,000 to 18,000

An average gas burner consumes about 4 feet of gas per hour or (600 x 4)

per burner . .	2400	units per hour.
Each flame from an oil lamp	430 to 515	" " "
each candle .	454 to 545	" " "

HEATING. (F. Schumann.)

Heat is transmitted:—

1st. By radiation: that is, the heated body giving out its heat in rays.

2nd. By convection, the heat being conveyed from the heated body through flues.

3rd. By conduction, the heat passing from a heated body to a colder, when in contact.

Heat is lost. Bodies are cooled—

1st. By radiation.

2nd. By contact, (with cold air or a colder body.)

3rd. By conduction.

Values of r.

Being the radiating and absorbing power of bodies in units of heat per sq. ft. for a difference of 1° F., from the experiments of Péclet.

Water	1.08530	Building Stones, Plaster, Wood and Brick	0.73580
Oil	1.48000	Zinc and Brass, polished	.04906
Iron, sheet	0.09200	Silver, silvered copper	0.02657
Iron, cast	0.64800	Woolen stuffs	0.75220
Lead, sheet	0.13286		
Paper	0.77060		
Glass	0.59480		

Conducting Power of Materials.

Being the units of heat transmitted per hour per sq. ft. of a plate one inch thick, the two surfaces differing in temperature 1°.

Copper	515	Pine, perpendicular to fibres	0.748
Iron	233	Pine, parallel to fibres	1.370
Zinc	225	Gutta percha	1.38
Lead	113	Cork	1.15
Marble	22 to 28	Charcoal, wood	0.636
Glass	6.600	Stagnant air	0.300
Plaster	3.860		
Cotton or wool	0.323		
Blotting paper, gray	0.274		

For double windows when the glass is not less than two inches apart, $c = 3.6$.

HOT WATER PIPES.

Heated body of cast iron r = 0.648.

Units of Heat, absorbed or emitted per square foot per hour.

Mean Temp. of Heated body, pipe, etc.	Temp. of Air and Walls.	Units of Heat per sq. foot per hour. By Contact. Air quiet	By Contact. Air moving	By Radiation.	By Radiation + Contact. Air quiet	By Radiation + Contact. Air moving
70	70	0	0	0	0	0
80	70	5.04	8.40	7.43	12.47	15.83
90	70	11.84	19.73	15.31	27.15	35.04
100	70	19.53	32.55	23.47	43.00	56.02
110	70	27.86	46.43	31.93	59.79	78.36
120	70	36.66	61.10	40.82	77.48	101.92
130	70	45.90	76.50	50.00	95.90	126.50
140	70	55.51	92.52	59.63	115.14	152.15
150	70	65.45	109.18	69.69	135.14	178.87
160	70	75.68	126.13	80.19	155.87	206.32
170	70	86.18	143.30	91.12	177.30	234.42
180	70	96.93	161.55	102.50	199.43	264.05
190	70	107.90	179.83	114.45	222.35	294.28
200	70	119.13	198.55	127.00	246.13	325.55
210	70	130.49	217.48	139.96	270.49	357.48

STEAM PIPES.

Heated body of cast iron r = 0.648.

Units of Heat, emitted or absorbed per square foot per hour.

Mean Temp. of Heated body, pipe, etc.	Temp. of Air and Walls.	Units of Heat per sq. foot per hour. By Contact. Air quiet	By Contact. Air moving	By Radiation.	By Radiation + Contact. Air quiet	By Radiation + Contact. Air moving
210	70	130.49	217.48	139.96	270.49	357.48
220	70	142.20	237.00	155.27	297.47	392.27
230	70	153.95	256.58	169.56	323.51	426.14
240	70	165.90	279.83	184.58	350.48	464.41
250	70	178.00	296.66	200.18	378.18	496.84
260	70	189.90	316.50	214.36	404.26	530.86
270	70	202.70	337.83	233.42	436.12	571.25
280	70	215.30	358.85	251.21	466.51	610.06
290	70	228.55	380.91	267.73	496.28	648.64
300	70	240.85	401.41	279.12	519.97	680.53

HOT WATER. (F. Schumann.)

Diameter of Pipes — Bore.

Connection pipes to coils. Upper story of a building, direct radiation.

Coil Surface.	Diam. of Pipe.	Sectional Area.
60 sq. ft. or less.	¾ inch.	0.44 sq. in.
100 " "	1 "	0.78 "
175 " "	1¼ "	1.22 "
250 " "	1½ "	1.76 "
600 " "	2 "	3.14 "

For each successive lower story increase the cross sectional area of pipe by 15 per cent. over that in the preceding story.

Basement or cellar of a building, indirect radiation.

Coil Surface.	Diam. of Pipe.	Sectional Area.
75 sq. ft. or less.	1 inch.	0.78 sq. in.
140 " "	1¼ "	1.22 "
225 " "	1½ "	1.76 "
500 " "	2 "	3.14 "

The sectional area of a branch pipe must equal the area of all the connections, and the area of a main pipe must equal the area of all the branches.

STEAM.

Diameter of Pipes — Bore.

When pressure of steam is not above 15 lbs. per sq. in. Connection pipe to coils — direct or indirect radiation.

Coil Surface.	Diam. of Pipe.	Sectional Area.
25 sq. ft. or less.	¾ inch.	0.44 sq. in.
40 " "	1 "	0.78 "
80 " "	1¼ "	1.22 "
160 " "	1½ "	1.76 "
250 " "	2 "	3.14

Table showing Units of Heat required per sq. ft. of heating surface per hour to heat 1 cubic foot of air at different temperatures.

Temp. of external air.	TEMPERATURE OF AIR IN ROOM.									
	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°
0°	0.822	1.028	1.234	1.439	1.645	1.851	2.056	2.262	2.467	2.673
10°	0.604	0.805	1.007	1.208	1.409	1.611	1.812	2.013	2.215	2.416
20°	0.393	0.590	0.787	0.984	1.181	1.378	1.575	1.771	1.968	2.165
30°	0.192	0.385	0.578	0.770	0.963	1.155	1.345	1.540	1.733	1.925
40°	0.000	0.188	0.376	0.564	0.752	0.940	1.128	1.316	1.504	1.692
50°	.....	0.000	0.184	0.367	0.551	0.735	0.918	1.102	1.286	1.470
60°	.....	.....	0.000	0.179	0.359	0.538	0.718	0.897	1.077	1.256
70°	.....	.....	.....	0.000	0.175	0.350	0.525	0.700	0.875	1.049

STEAM PRESSURE 1 LB. PER SQUARE INCH 215.5.°

Diameter of steam supply pipes and square feet of radiating surface which they will furnish with steam if placed from 9 to 625 feet from boiler.

Diam. of pipe in inches.	DISTANCE OF RADIATOR FROM BOILER IN FEET.							
	9	64	100	225	324	400	484	625
	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.
¾	146	55	44	29	24	22	20	17
1	301	113	90	60	50	41	41	36
1¼	529	198	158	106	88	79	72	63
1½	832	312	249	166	139	124	113	99
2	1707	640	512	341	284	256	233	205
2½	2982	1118	894	596	497	447	406	357
3	4708	1765	1412	941	784	706	642	565
3½	6919	2595	2075	1384	1153	1037	943	828
4	9146	3429	2743	1889	1524	1371	1247	1097
4½	12966	4862	3889	2593	2161	1944	1768	1555
5	17005	6377	5101	3401	2834	2550	2319	2040
6	26628	9985	7988	5325	4438	3994	3631	3195
7	39150	14684	11747	7831	6526	5873	5340	4698
8	54679	20504	16404	10936	9113	8202	7456	6560
9	73659	27622	22098	14731	12276	11049	10044	8836
10	95496	35811	28648	19099	15916	14324	13022	11459

STEAM PRESSURE 10 LBS. PER SQUARE INCH.

Diam. of steam pipe in inches.	DISTANCE OF RADIATOR FROM BOILER IN FEET.							
	9	64	100	225	324	400	484	625
	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.
¾	366	137	109	73	61	55	50	44
1	752	282	225	150	125	112	102	90
1¼	1312	492	393	262	218	196	179	157
1½	2074	777	622	415	345	311	281	249
2	4244	1591	1273	848	707	636	578	509
2½	7436	2788	2231	1487	1239	1115	1014	892
3	11702	4388	3510	2340	1950	1755	1595	1404
3½	17205	6452	5161	3441	2884	2580	2346	2064
4	24042	9016	7212	4808	4007	3606	3278	2884
4½	32292	12109	9687	6458	5382	4843	4403	3873
5	42013	17505	12604	8402	7002	6302	5729	5040
6	67564	25337	20269	13513	11260	10134	9213	8107
7	97372	36514	29211	19474	16228	14605	13278	11684
8	136209	51078	40862	27242	22701	20431	18574	16344
9	182995	68608	54886	36591	30492	27443	24948	21954
10	237973	89240	71392	47594	39662	35696	32451	28556

TABLE OF STANDARD DIMENSIONS OF WROUGHT IRON WELDED PIPE FOR STEAM, GAS OR WATER.

Inside Diameter (Nominal).	Actual Outside Diameter.	Thickness.	Actual Inside Diameter.	Internal Circumference.	External Circumference.	Length of Pipe per sq. ft. of Inside Surface.	Length of Pipe per sq. ft. of Outside Surface.	Internal Area.	External Area.	Length of Pipe containing one cubic foot.	Weight per foot of length.	Number of Threads per inch, of Screw.
	inches.	inches.	inches.	inches.	inches.	feet.	feet.	inches.	inches.	feet.	pounds.	
1/8	0.405	0.068	0.270	0.848	1.272	14.15	9.44	0.0572	0.129	2500.0	0.243	27
1/4	0.54	0.088	0.364	1.144	1.696	10.50	7.075	0.1041	0.229	1385.0	0.422	18
3/8	0.675	0.091	0.494	1.552	2.121	7.67	5.657	0.1916	0.358	751.5	0.561	18
1/2	0.84	0.109	0.623	1.957	2.652	6.13	4.502	0.3048	0.554	472.4	0.845	14
3/4	1.05	0.113	0.824	2.589	3.299	4.635	3.637	0.5333	0.866	270.0	1.126	14
1	1.315	0.134	1.048	3.292	4.134	3.679	2.903	0.8627	1.357	166.9	1.670	11½
1¼	1.66	0.140	1.380	4.335	5.215	2.768	2.301	1.496	2.164	96.25	2.258	11½
1½	1.9	0.145	1.611	5.061	5.969	2.371	2.01	2.038	2.835	70.65	2.694	11½
2	2.375	0.154	2.067	6.494	7.461	1.848	1.611	3.355	4.430	42.36	3.667	11½
2½	2.875	0.204	2.468	7.754	9.032	1.547	1.328	4.783	6.491	30.11	5.773	8
3	3.5	0.217	3.067	9.636	10.996	1.245	1.091	7.388	9.621	19.49	7.547	8
3½	4.0	0.226	3.548	11.146	12.566	1.077	0.955	9.887	12.566	14.56	9.055	8
4	4.5	0.237	4.026	12.648	14.137	0.949	0.849	12.730	15.904	11.31	10.728	8
4½	5.0	0.247	4.508	14.153	15.708	0.848	0.765	15.939	19.635	9.03	12.492	8
5	5.563	0.259	5.045	15.849	17.475	0.757	0.629	19.990	24.299	7.20	14.564	8
6	6.625	0.280	6.065	19.054	20.813	0.63	0.577	28.889	34.471	4.98	18.767	8
7	7.625	0.301	7.023	22.063	23.954	0.544	0.505	38.737	45.663	3.72	23.410	8
8	8.625	0.322	7.982	25.076	27.096	0.478	0.444	50.039	58.426	2.88	28.348	8
9	9.688	0.344	9.001	28.277	30.433	0.425	0.394	63.633	73.715	2.26	34.077	8
10	10.75	0.366	10.019	31.475	33.772	0.381	0.355	78.838	90.762	1.80	40.641	8

From "Steam Heating for Buildings," by WM. J. BALDWIN, M. E.

TABLE SHOWING THE RELATIVE AREAS OF STANDARD WROUGHT IRON, GAS, WATER AND STEAM PIPE FROM 1-8 TO 9 INCHES INCLUSIVE.

	1/8	1/4	3/8	1/2	3/4	1	1¼	1½	2	2½	3	3½	4	5	6	7	8	9
1/8	1.00	4.00	9.00	16.00	36.00	64.00	81.00	144.00	256.00	400.00	576.00	784.00	1024.00	1600.00	2304.00	3136.00	4096.00	5184.00
1/4	....	1.00	2.25	4.00	9.00	16.00	25.00	36.00	64.00	100.00	144.00	196.00	256.00	400.00	576.00	784.00	1024.00	1296.00
3/8	....	....	1.00	1.77	4.00	7.11	11.11	16.00	28.4	44.4	64.00	87.1	113.7	155.5	256.00	348.4	455.1	574.8
1/2	....	....	....	1.00	2.25	4.00	6.25	9.00	16.00	25.00	36.00	49.00	64.00	100.00	144.00	196.00	256.00	324.00
3/4	....	....	....	....	1.00	1.77	2.77	4.00	7.11	11.1	16.00	21.7	28.1	44.4	64.00	87.1	113.7	144.00
1	....	....	....	....	....	1.00	1.56	2.25	4.00	6.25	9.00	12.2	16.00	25.00	36.00	49.00	64.00	81.00
1¼	....	....	....	....	....	....	1.00	1.44	2.56	4.00	5.76	7.84	10.24	16.00	21.4	31.36	40.96	51.44
1½	....	....	....	....	....	....	....	....	1.77	2.77	4.00	5.44	7.11	11.1	16.00	21.7	28.4	36.00
2	....	....	....	....	....	....	....	....	1.00	1.56	2.25	3.06	4.00	6.25	9.00	12.25	16.00	20.25
2½	....	....	....	....	....	....	....	....	....	1.00	1.44	1.96	2.56	4.00	5.76	7.84	10.24	12.96
3	....	....	....	....	....	....	....	....	....	....	1.00	1.81	1.77	2.77	4.00	5.44	7.11	9.00
3½	....	....	....	....	....	....	....	....	....	....	....	1.00	1.30	2.04	2.93	4.00	5.22	5.6
4	....	....	....	....	....	....	....	....	....	....	....	....	1.00	1.56	2.25	3.06	4.00	5.06
5	....	....	....	....	....	....	....	....	....	....	....	....	....	1.00	1.44	1.96	2.56	3.24
6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.00	1.81	1.77	2.25
7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.00	1.30	1.65
8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.00	1.26

From "Steam Heating for Buildings," by Wm. J. Baldwin, M. E.

PART IV.

NOTES ON GAS.

FAT BITUMINOUS COALS IN THE STATE OF OHIO.

County.	Locality.	Designation of Coal Beds.	By whom Analyzed.	Specific Gravity.	Analysis. Carbon.	Volatile Matter.	Ashes.
Portland.	Talmadge.....	Upson's Mine	W. W. Mather	1.264	53.404	44.298	2.2[illegible]
Jackson..	Lick Township	....	"	1.283	49.882	47.327	2.221
"	Madison Township.........	....	J. L. Cassels..	1.560	39.950	44.800	14.600
"	Madison Township..........	Cannel Coal..	"	1.410	......	......	......
....	Carr's Run....	....	R. C. Taylor..	1.270	......	......	......
....	Pomeroy......	....	Dr. J. Percy...	.....	76.70	18.70	4.60

FAT BITUMINOUS COALS IN PENNSYLVANIA.

County.	Locality.	Designation of Coal Beds.	By whom Analyzed.	Specific Gravity.	Analysis. Carbon.	Volatile Matter.	Ashes.
Venango	Shippensville..	Sandy Ridge.	H. D. Rogers, State Report	.....	49.80	43.20	7.00
"	6. M. F. of Franklin.....	....	"	.....	29.54	52.78	17.68
Beaver..	Greersburg....	....	"	.....	30.12	36.00	33.88
Crawford	Conneaut Lake	....	"	.....	59.45	38.75	1.80
Mercer..	Greensville....	....	"	.....	57.80	40.50	1.70
....	"	....	R. C. Taylor..	.....	......	......	......
....	Orangeville....	....	State Report..	1.25	53.45	43.75	2.80

Mixing Gases to make a desired Candle Power.

To find the number of cubic feet of each of two gases of known candle power to produce 1000 cubic feet of a desired candle power,

Let a = a gas of 16 candles.
Let b = a gas of 67 candles.
Let c = the desired candle power, say 25.
Let x = the required quantity of one of the gases, say 16 candles.
1000 the volume in cubic feet of the mixture.

Formula.

$$ax + b\,(1000 - x) = c1000.$$

Substituting the given values for the symbols, we have in the following example:

$$16x + 67\,(1000 - x) = 2500$$
$$-51x + 67000 \qquad = 2500$$
$$-51x = 25000 - 67000;$$
$$\therefore x = \frac{42000}{51} = 823.5 \text{ cubic feet of 16 candle gas.}$$

Then, $1000 - 823.5 = 176.5$ cubic feet of 67 candle gas.

Proof.

$$823.5 \times 16 = 131760$$
$$\frac{176.5 \times 67}{1000} = 118255 = \frac{25000}{1000} = 25 \text{ candle gas.}$$

Formula for ascertaining the quantity of rich gas necessary to be added to a given quantity of poor gas to raise it to a desired candle power.

Example.—To 500 cubic feet of 16 candle gas how many feet of 30 candle gas must be added to raise it to 20 candles?

$$500 \times 16 = 8000$$
$$x \times 30 = \quad 30x$$
$$500x + x = \quad 8000 + 30x;$$
$$\text{and } \frac{8000 + 30x}{500 + x} = 20 \text{ candles.}$$
$$\therefore x = 200 \text{ feet.}$$

Given, the *candle power* of a mixture and the candle power and *percentages of one of the gases*, to find the candle power of the other.

Example.—Suppose we have 97 per cent. of a 15 candle gas and 3 per cent. of an unknown gas. The illuminating power of the mixture is found to be 20 candles. What is the illuminating power of the unknown gas?

Let x = the illuminating power of the unknown gas.

$$\begin{array}{rcl} 97 \times 15 & = & 1455 \\ 3 \times x & = & 3x \\ \hline 100 & & 1455 + 3x. \end{array}$$

$$\frac{1455 + 3x}{100} = 20 \text{ candle gas.}$$

$\therefore x = 181.6$ candles, the illuminating power of the rich gas.

Atmospheric Air in Gas.

Having the candle power *of the mixture* and the candle power of the gas, to find the percentage of atmospheric air.

The value of atmospheric air is taken as —50.

Example.—To find the percentage of air in an 18 candle gas, the illuminating power of the mixture being 14 candles.

Let x = percentage of gas.

Let y = percentage of air.

$$\begin{array}{rcl} x \times 18 & = & 18x \\ y \times 50 & - & 50y \\ \hline x + y & & 18x - 50y. \end{array}$$

Then, $x + y = 100$, and $x = 100 - y$.

$$\frac{18x - 50y}{100} = 14 \text{ candles.}$$

$$\therefore x = \frac{1400 + 50y}{18}.$$

Substituting the above value of x, we have:

$$100 - y = \frac{1400 + 50y}{18}.$$

$$\therefore y = 5.88 \text{ per cent.}$$

GAS-HOLDERS.

Formulæ for Weight, Pressure, and Diameter.

Let—

W = weight in pounds;
P = pressure in inches of water;
D = diameter of holder in feet

Then—

$$D^2 \times P \times 4.09 = W \text{ (in pounds.)}$$

$$\frac{W}{D^2 \times 4.09} = P \text{ (in inches of water.)}$$

$$\sqrt{\frac{W}{P \times 4.09}} = D \text{ (in feet.)}$$

Example.

Let Diameter of Holder	=	....	51.5 feet.
Pressure	" =	....	2.7 inches.
Weight	" =	....	29288. pounds.

$W = 51.5^2 \times 2.7 \times 4.09 =$ .... 29288 pounds.

$P = \dfrac{29288.}{2652.25 \times 4.09} =$ .... 2.7 inches.

$D = \sqrt{\dfrac{29288.}{2.7 \times 4.09}} =$ .... 51 feet 6 inches.

The first formula gives Weight from diameter and pressure.
" second " " Pressure " " " weight.
" third " " Diameter " pressure and weight.

A column of distilled water one foot high gives a pressure of 1000 ounces, or 62.5 pounds on a square foot of surface.

A column one inch high gives 5.2 pounds on a square foot.
" " " 253 grains " " inch.
" " " 197 " " round inch.

TABLE OF THE WEIGHTS OF GASHOLDERS.

In Pounds for every One-tenth of an Inch maximum Pressure, and from 20 to 200 Feet in Diameter.

Diameter of Gasholder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.
20	164	53	1149	86	3026	119	5793
21	181	54	1193	87	3097	120	5891
22	198	55	1238	88	3168	121	5990
23	217	56	1283	89	3241	122	6089
24	236	57	1329	90	3314	123	6189
25	256	58	1376	91	3388	124	6290
26	277	59	1424	92	3463	125	6392
27	298	60	1473	93	3538	126	6495
28	321	61	1522	94	3615	127	6598
29	344	62	1573	95	3692	128	6703
30	368	63	1624	96	3770	129	6808
31	393	64	1676	97	3849	130	6914
32	419	65	1729	98	3929	131	7021
33	446	66	1782	99	4010	132	7128
34	473	67	1837	100	4091	133	7237
35	501	68	1892	101	4173	134	7346
36	530	69	1948	102	4256	135	7456
37	560	70	2005	103	4340	136	7567
38	591	71	2062	104	4425	137	7678
39	622	72	2121	105	4510	138	7791
40	655	73	2180	106	4597	139	7904
41	688	74	2240	107	4684	140	8018
42	722	75	2301	108	4772	141	8133
43	757	76	2363	109	4861	142	8249
44	792	77	2426	110	4950	143	8366
45	828	78	2489	111	5041	144	8483
46	866	79	2553	112	5132	145	8601
47	904	80	2618	113	5224	146	8720
48	943	81	2684	114	5317	147	8840
49	982	82	2751	115	5410	148	8961
50	1023	83	2818	116	5505	149	9083
51	1064	84	2887	117	5600	150	9205
52	1106	85	2956	118	5696	200	16364

To ascertain the weight of a Gasholder by the above table, the diameter and maximum pressure being known.

RULE.—Multiply the number of lbs. standing opposite the diameter by the pressure in tenths of an inch.

EXAMPLE.—What is the weight of a Gasholder 78 feet in diameter, giving a maximum pressure of 32-10ths.

$2489 \times 32 = 79{,}648$ lbs., weight of Gasholder.

To ascertain, by the above table, the pressure which a Gasholder will give, the diameter and weight being known.

RULE.—Divide the weight in lbs. of the Gasholder by the weight given opposite the diameter.

EXAMPLE.—What pressure will a Gasholder give whose weight is 32,075, and diameter 56 feet.

$32{,}075 \div 1283 = 25$-10ths, maximum pressure of Gasholder.

Gas Works.

Each lamp consumes 5 cubic feet per hour.

In winter each lamp consumes from 1800 to 2500 cubic feet per month.

In summer each lamp consumes from 1000 to 1800 cubic feet per month.

Average consumption for each lamp = 21000 cu. ft. per year.

Private burners about = 5000 cu. ft. per year.

Motion of Gas in Pipes.

Q = Quantity of Gas, in cubic feet per hour.
L = Length of pipe, in yards.
D = Diameter of pipe, in inches.
H = Head of water pressure, in inches.
G = Specific gravity of gas.

$$Q = 1350\, D^2 \sqrt{\frac{H\,D}{G\,L}}$$

$$D = .056 \sqrt[5]{\frac{Q^2 G\,L}{H}}$$

G May be assumed = .42 for ordinary calculations.
H " " " = ½ an inch to 1 inch.

Services for Lamps.

2	Lamps	40	feet	from	main	require	⅜	bore	of	pipe
4	"	40	"	"	"	"	½	"	"	"
6	"	50	"	"	"	"	⅝	"	"	"
10	"	100	"	"	"	"	¾	"	"	"
15	"	130	"	"	"	"	1	"	"	"
20	"	150	"	"	"	"	1¼	"	"	"
25	"	180	"	"	"	"	1½	"	"	"
30	"	200	"	"	"	"	1¾	"	"	"

Seldom use less than ¾ in

TABLE

Showing the Discharges of Gas in Cubic Feet per hour.
Specific Gravity, 0.420; Pressure, 1 inch.

Length of Pipes, in yds.	DIAMETER OF PIPES, IN INCHES.										
	2	3	4	6	8	10	12	16	18	20	24
20	2291	7253	......	......	......	......	......	......	......	......	......
30	2149	5941	12160	......	......	......	......	......	......	......	......
40	1859	5127	11340	28965	......	......	......	......	......	......	......
50	1666	4580	9417	25758	53308	......	......	......	......	......	......
100	1177	3244	6652	18322	37670	65475	......	......	......	......	......
150	961	2653	5421	14968	30758	53970	84758	......	......	......	......
200	833	2284	4708	12976	26611	46575	73288	150681	201986	......	......
250	745	2053	4212	11566	23847	42580	65793	134744	179252	235440	......
300	679	1871	3844	10594	21686	37935	59875	123033	164899	214920	392418
400	589	1615	3326	9136	18576	32845	51904	106464	139530	186840	344050
500	529	1433	2980	8164	16848	29439	46461	95785	127714	164700	308458
600	480	1324	2721	7481	15292	26865	43379	87145	116785	151740	281080
700	442	1227	2505	6901	14169	24840	39288	80924	108037	140400	260091
800	......	1142	2354	6463	13305	23220	36547	75740	101039	131220	243664
900	......	1081	2203	6075	12268	21870	34599	71248	95653	124200	228062
1000	......	1020	2095	5783	11836	20790	32853	67382	90541	117720	218111
1760	......	......	1576	4374	8985	17010	24688	50803	68234	88560	164152
2640	......	......	1296	3547	7257	12690	20217	41512	55549	72360	134152
3520	......	......	1123	3013	6307	11070	17526	35942	48114	62640	115900
5280	......	......	......	2527	5184	9040	14191	28030	39366	50760	94910
7040	......	......	......	......	4496	7836	12247	25228	34117	44280	82134
8800	......	......	......	......	......	7020	10886	22464	29305	39420	73008
10000	......	......	......	......	......	......	10303	21082	28431	36720	68445

TABLE

Comparing the Specific Gravity of Gas (Air being 1.000) with the Illuminating Power in Standard Sperm Candles.

No. of Candles.		Specific Gravity.	No. of Candles.		Specific Gravity.
10	Equal to about..........	.380	21	Equal to about..........	.522
11	" "	.392	22	" "	.537
12	" "	.405	23	" "	.550
13	" "	.416	24	" "	.565
14	" "	.430	25	" "	.585
15	" "	.443	26	" "	.605
16	" "	.455	27	" "	.625
17	" "	.468	28	" "	.645
18	" "	.482	29	" "	.662
19	" "	.495	30	" "	.678
20	" "	.508	31	" "	.694

TABLE OF AQUEOUS VAPOR

Contained in 1000 Cubic Feet of Gas at Indicated Temperature.

Temp. Degrees.	Volume. A. V.	Temp. Degrees.	Volume. A. V.	Temp. Degrees.	Volume. A. V.
40	9.33	54	15.33	68	24.06
41	9.73	55	15.86	69	24.83
42	10.13	56	16.40	70	25.66
43	10.53	57	16.93	71	26.53
44	10.93	58	17.53	72	27.40
45	11.33	59	18.10	73	28.30
46	11.73	60	18.66	74	29.23
47	12.13	61	19.23	75	30.20
48	12.53	62	19.80	76	31.20
49	12.93	63	20.50	77	32.20
50	13.33	64	21.20	78	33.23
51	13.80	65	21.90	79	34.23
52	14.26	66	22.60	80	35.33
53	14.80	67	23.30		

FLOW OF GAS THROUGH MAINS (Per Hour).

	With Loss of $\frac{5}{10}$ of an Inch Pressure.				With Loss of 1 Inch Pressure.			
Diameter.	50 ft.	100 ft.	500 ft.	1000 ft.	50 ft.	100 ft.	500 ft.	1000 ft.
2 inch.	2000	1600	700	500	3500	2800	1250	875
3 "	4700	3750	1600	1200	7900	6300	2800	2000
4 "	8500	7000	2900	2200	14000	11500	5000	3600
6 "	19000	15000	6500	5000	32000	26000	12000	9000
8 "	36000	29000	13000	10000	58000	47000	22000	15000
10 "	65000	52000	23000	18000	90000	75000	33000	23500
12 "	100000	80000	36000	30000	135000	113000	50000	36000

EFFECT OF BAROMETRIC PRESSURE UPON GASES.

Additional Pressure. Feet of Water.	Relation to Original Volume.	Total Pressure in feet of Water.
0	1	33 + 0 = 33
1	$\frac{33}{34}$	33 + 1 = 34
2	$\frac{33}{35}$	33 + 2 = 35
3	$\frac{33}{36}$	33 + 3 = 36
4	$\frac{33}{37}$	33 + 4 = 37
5	$\frac{33}{38}$	33 + 5 = 38
10	$\frac{33}{43}$	33 + 10 = 43
20	$\frac{33}{53}$	33 + 20 = 53
30	$\frac{33}{63}$	33 + 30 = 63
33	$\frac{33}{66}$	33 + 33 = 66

$\frac{33}{66} = \frac{1}{2}$ volume for 1 atmosphere additional.

TABLE

Showing the number of candles any other light is equal to, the cent of candle being 10 inches from centre of Photometer, and the g (or other light) at any distance from 5 to 50 inches.

Distance of Gas Burner from Photom'r.	Number of Candles Gas Burner is equal to.	Distance.	Candles.	Distance.	Candles.	Distance.	Candles.
5 in.	.25	16 in.	2.56	27½ in.	7.56	39 in.	15.2[illegible]
5½ "	.30	16½ "	2.72	28 "	7.84	39½ "	15.[illegible]
6 "	.36	17 "	2.80	28½ "	8.12	40 "	16.00
6½ "	.42	17½ "	3.06	29 "	8.41	40½ "	16.40
7 "	.49	18 "	3.24	29½ "	8.70	41 "	16.81
7½ "	.56	18½ "	3.42	30 "	9.00	41½ "	17.22
8 "	.64	19 "	3.61	30½ "	9.30	42 "	17.64
8½ "	.72	19½ "	3.80	31 "	9.61	42½ "	18.06
9 "	.81	20 "	4.00	31½ "	9.92	43 "	18.49
9½ "	.90	20½ "	4.20	32 "	10.24	43½ "	18.92
10 "	1.00	21 "	4.41	32½ "	10.56	44 "	19.36
10½ "	1.10	21½ "	4.62	33 "	10.89	44½ "	19.80
11 "	1.21	22 "	4.84	33½ "	11.22	45 "	20.25
11½ "	1.32	22½ "	5.06	34 "	11.56	45½ "	20.70
12 "	1.44	23 "	5.29	34½ "	11.90	46 "	21.16
12½ "	1.56	23½ "	5.52	35 "	12.25	46½ "	21.62
13 "	1.69	24 "	5.76	35½ "	12.60	47 "	22.09
13½ "	1.82	24½ "	6.00	36 "	12.96	47½ "	22.56
14 "	1.96	25 "	6.25	36½ "	13.32	48 "	23.04
14½ "	2.10	25½ "	6.50	37 "	13.69	48½ "	23.52
15 "	2.25	26 "	6.76	37½ "	14.06	49 "	24.01
15½ "	2.40	26½ "	7.02	38 "	14.44	49½ "	24.50
....	....	27 "	7.29	38½ "	14.82	50 "	25.00

TABLE

Showing the Per Centage of Error in Meters, according as their Registration differs from that of the Test Gas Holders.

The sign + is used to indicate FAST, and — to indicate SLOW.

Meters not exceeding 2 Per Cent. fast, or 3 Per Cent. slow, are correct within the meaning of the English "SALES OF GAS ACT."

Meter Registering 2 Feet.		Meter Registering 2 Feet.		Meter Registering 5 Feet.		Meter Registering 5 Feet.		Meter Registering 10 Feet.		Meter Registering 10 Feet.	
Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
1·90	+5·26	2·01	—0·50	4·90	+2·04	5·01	—0·20	9·90	+1·01	10·01	—0·10
·91	+4·71	·02	—0·99	·91	+1·83	·02	—0·40	·91	+0·91	·02	—0·20
·92	+4·17	·03	—1·48	·92	+1·63	·03	—0·60	·92	+0·81	·03	—0·30
·93	+3·63	·04	—1·96	·93	+1·42	·04	—0·79	·93	+0·70	·04	—0·40
·94	+3·09	·05	—2·44	·94	+1·21	·05	—0·99	·94	+0·60	·05	—0·50
·95	+2·56	·06	—2·91	·95	+1·01	·06	—1·19	·95	+0·50	·06	—0·60
·96	+2·04	·07	—3·38	·96	+0·81	·07	—1·38	·95	+0·40	·07	—0·70
·97	+1·52	·08	—3·85	·97	+0·60	·08	—1·57	·97	+0·30	·08	—0·79
·98	+1·01	·09	—4·31	·98	+0·40	·09	—1·77	·98	+0·20	·09	—0·89
·99	+0·50	10	—4·76	·99	+0·20	·10	—1·96	·99	+0·10	·10	—0·99
2·00	Nil.	....	....	5·00	Nil.	....	....	10·00	Nil.	....	....

YEARLY TABLE OF GAS BURNING HOURS.

Showing the number of hours from sunset to ten o'clock at night for each month in the year, with the average for each month and the comparative length of the evenings.

Month.	Total per Month.	Average per Night.	Comparative Length of Evenings.
June	76 hrs. 55 min.	2 hrs. 34 min.	100
July	83 " 52 "	2 " 42 "	100
May	88 " 38 "	2 " 51 "	115
August	99 " 16 "	3 " 12 "	132
April	102 " 47 "	3 " 25 "	134
September	115 " 24 "	3 " 51 "	150
March	127 " 06 "	4 " 06 "	165
February	132 " 59 "	4 " 55 "	172
October	140 " 41 "	4 " 31 "	182
November	153 " 35 "	5 " 07 "	199
January	163 " 16 "	5 " 16 "	212
December	168 " 25 "	5 " 26 "	218

SERVICE METERS AND BURNERS.

This table is the standard of the principal gas works. It governs the size of pipe used by gas fitters for consumers, and will be found of value. From it, small works can determine the size of their mains, which should never be under size, as the difference in cost is not proportionate to the advantages. Every service should have a T so placed as to be easily opened for the purpose of clearing the service pipe should any obstruction in it occur.

Size Tubing.	Threads per Inch.	Weight per Foot.	Length allowed.	Number of Burners.
1/8	27	.243	2 feet.	1
1/4	18	.422	6 "	1
3/8	14	.561	20 "	3
1/2	14	.845	30 "	6
3/4	11 1/2	1.126	50 "	20
1	11 1/2	1.670	70 "	35
1 1/4	11 1/2	2.258	100 "	60
1 1/2	11 1/2	2.694	150 "	100
2	8	3.367	200 "	200
2 1/2	8	5.773	300 "	300
3	8	7.547	450 "	450
4	8	10.728	600 "	750

Lead Connections.	Size of Meter.	Tested for	Greatest Number.
1/2	2 lights.	2 6-ft. burners.	4
1/2	3 "	3 "	8
5/8	5 "	5 "	12
3/4	10 "	10 "	20
1	20 "	20 "	40
1 1/4	30 "	30 "	50
1 1/2	45 "	45 "	80
2	60 "	60 "	100
2	80 "	80 "	130
..	100 "	100 "	180
..	150 "	150 "	250
..	200 "	200 "	350
..	250 "	250 "	400
..	300 "	300 "	500
..	400 "	400 "	650

Given, the *candle power* of a mixture and the candle power and *percentages of one of the gases*, to find the candle power of the other.

Example.—Suppose we have 97 per cent. of a 15 candle gas and 3 per cent. of an unknown gas. The illuminating power of the mixture is found to be 20 candles. What is the illuminating power of the unknown gas?

Let $x =$ the illuminating power of the unknown gas.

$$\begin{array}{rcl} 97 \times 15 & = & 1455 \\ 3 \times x & = & 3x \\ \hline 100 & & 1455 + 3x. \end{array}$$

$$\frac{1455 + 3x}{100} = 20 \text{ candle gas.}$$

$\therefore$ $x = 181.6$ candles, the illuminating power of the rich gas.

Atmospheric Air in Gas.

Having the candle power *of the mixture* and the candle power of the gas, to find the percentage of atmospheric air.

The value of atmospheric air is taken as -50.

Example.—To find the percentage of air in an 18 candle gas, the illuminating power of the mixture being 14 candles.

Let $x =$ percentage of gas.

Let $y =$ percentage of air.

$$\begin{array}{rcl} x \times 18 & = & 18x \\ y \times 50 & - & 50y \\ \hline x + y & & 18x - 50y. \end{array}$$

Then, $x + y = 100$, and $x = 100 - y$.

$$\frac{18x - 50y}{100} = 14 \text{ candles.}$$

$$\therefore x = \frac{1400 + 50y}{18}.$$

Substituting the above value of x, we have:

$$100 - y = \frac{1400 + 50y}{18}.$$

$$\therefore y = 5.88 \text{ per cent.}$$

GAS-HOLDERS.

Formulæ for Weight, Pressure, and Diameter.

Let—

W = weight in pounds;
P = pressure in inches of water;
D = diameter of holder in feet

Then—

$$D^2 \times P \times 4.09 = W \text{ (in pounds.)}$$

$$\frac{W}{D^2 \times 4.09} = P \text{ (in inches of water.)}$$

$$\sqrt{\frac{W}{P \times 4.09}} = D \text{ (in feet.)}$$

Example.

Let Diameter of Holder	=	....	51.5 feet.
Pressure "	=	....	2.7 inches.
Weight "	=	....	29288. pounds.

$$W = \overline{51.5}^2 \times 2.7 \times 4.09 = \ldots\ldots\ldots \quad 29288 \text{ pounds.}$$

$$P = \frac{29288.}{2652.25 \times 4.09} = \ldots\ldots\ldots \quad 2.7 \text{ inches.}$$

$$D = \sqrt{\frac{29288.}{2.7 \times 4.09}} = \ldots\ldots\ldots\ldots \quad 51 \text{ feet } 6 \text{ inches.}$$

The first formula gives Weight from diameter and pressure.
" second " " Pressure " " " weight.
" third " " Diameter " pressure and weight.

A column of distilled water one foot high gives a pressure of 1000 ounces, or 62.5 pounds on a square foot of surface.

A column one inch high gives 5.2 pounds on a square foot.
" " " 253 grains " " inch.
" " " 197 " " round inch.

TABLE OF THE WEIGHTS OF GASHOLDERS.

In Pounds for every One-tenth of an Inch maximum Pressure, and from 20 to 200 Feet in Diameter.

Diameter of Gasholder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs for each one-tenth of an inch Pressure.
20	164	53	1149	86	3026	119	5793
21	181	54	1193	87	3097	120	5891
22	198	55	1238	88	3168	121	5990
23	217	56	1283	89	3241	122	6089
24	236	57	1329	90	3314	123	6189
25	256	58	1376	91	3388	124	6290
26	277	59	1424	92	3463	125	6392
27	298	60	1473	93	3538	126	6495
28	321	61	1522	94	3615	127	6598
29	344	62	1573	95	3692	128	6703
30	368	63	1624	96	3770	129	6808
31	393	64	1676	97	3849	130	6914
32	419	65	1729	98	3929	131	7021
33	446	66	1782	99	4010	132	7128
34	473	67	1837	100	4091	133	7237
35	501	68	1892	101	4173	134	7346
36	530	69	1948	102	4256	135	7456
37	560	70	2005	103	4340	136	7567
38	591	71	2062	104	4425	137	7678
39	622	72	2121	105	4510	138	7791
40	655	73	2180	106	4597	139	7904
41	688	74	2240	107	4684	140	8018
42	722	75	2301	108	4772	141	8133
43	757	76	2363	109	4861	142	8249
44	792	77	2426	110	4950	143	8366
45	828	78	2489	111	5041	144	8483
46	866	79	2553	112	5132	145	8601
47	904	80	2618	113	5224	146	8720
48	943	81	2684	114	5317	147	8840
49	982	82	2751	115	5410	148	8961
50	1023	83	2818	116	5505	149	9083
51	1064	84	2887	117	5600	150	9205
52	1106	85	2956	118	5696	200	16364

To ascertain the weight of a Gasholder by the above table, the diameter and maximum pressure being known.

RULE. —Multiply the number of lbs. standing opposite the diameter by the pressure in tenths of an inch.

EXAMPLE —What is the weight of a Gasholder 78 feet in diameter, giving a maximum pressure of 32-10ths.

2489 × 32 = 79,648 lbs., weight of Gasholder.

To ascertain, by the above table, the pressure which a Gasholder will give, the diameter and weight being known.

RULE. —Divide the weight in lbs. of the Gasholder by the weight given opposite the diameter.

EXAMPLE. —What pressure will a Gasholder give whose weight is 32,075, and diameter 56 feet.

32,075 ÷ 1283 = 25-10ths, maximum pressure of Gasholder.

The Findlay Ohio natural gas as determined by Prof. C. C. Howard, gives:

	Per Cent.
Marsh Gas	92.61
Olefiant Gas	.30
Hydrogen	2.18
Nitrogen	3.61
Oxygen	.34
Carbonic Acid	.50
Carbonic Oxide	.26
Sulphuretted Hydrogen	.20
	100.00

HEATING POWER OF NATURAL GAS.

The Committee of the Engineers Society of Western Pennsylvania on natural gas state that "a boiler which evaporated nine pounds of water per pound of coal consumed, evaporated 20 $\frac{31}{100}$ pounds of water to the pound of gas consumed. Taking a pound of gas (pressure not stated) to be 23½ cubic feet, this indicates a pound of gas to be equivalent to 2.2235 pounds of coal, and a pound of coal to equal in value 10.42 feet of gas." The committee further state their belief to be that with a boiler well adapted to heating by gas the value of a pound of coal would be only 7½ cubic feet of gas. It explodes violently when mixed with from nine to fourteen parts of air. The flame temperature of natural gas when burned with pure oxygen, is estimated by Mr. F. W. Taylor at 7100° C., and of the Siemen's producer gas at 2850° C., when burned with just enough air to insure perfect combination, the temperatures are estimated at 2333° C. for natural gas, and 1700° C. for Siemen's.

From a monograph by Mr. Paine, in Forney's Railroad and Engineering Journal.

The following table is taken from a report on the chemical composition of natural gas by Prof. Francis C. Phillips, of the Western University, Alleghany, for the geological survey of Pennsylvania.

FUEL VALUE OF NATURAL GAS.

Gas Fields.	2		3	4	5	6	7
	Weight in Kilos of Carbon per Cubic Meter of Paraffins.	Weight in Kilos of Hydrogen per Cubic Meter of Paraffins.	Factor.	Available Heat Units per Cubic Meter of Gas.	Available Heat Units per 100 Feet of Gas.	Pounds of Water at Boiling Point Evaporated by 100 Feet of Gas.	Pounds of Pure Charcoal equal in Heating Effect to 100 Feet of Gas.
Fredonia.......	0.80406	0.22492	0.9224	11449	32421	133.3	8.845
Sheffield.... ..	0.65526	0.19924	0.9152	10040	28430	116.89	7.756
Kane..........	0.65569	0.19866	0.9152	10354	20319	120.54	7.999
Wilcox........	0.64622	0.19828	0.9152	9925	28102	115.54	7.667
Speechley......	0.69857	0.20738	0.9173	11144	31554	129.73	8.609
Lyon's Run, near Murrysville..	0.53741	0.17950	0.9081	9296	26321	108.22	7.181
Raccoon Creek.	0.62918	0.19408	0.9152	9661	27355	112.47	7.463
Baden.........	0.64209	0.19677	0.9152	9515	26941	110.77	7.350
Houston.......	0.64737	0.19694	0.9152	9224	26119	107.38	7.126

The factor of column 3 is the decimal equivalent of a common fraction, whose numerator represents the actual number of heat units produced in the burning of the unit weight of the total paraffins, the number being ascertained from a consideration of the percentage of carbon and hydrogen in the gas. The denominator represents the number of heat units obtained when the quantities of contained carbon and hydrogen are multiplied by the numbers 8080 and 34180 respectively, and the products added.

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